Strategies of Incumbent Car Manufacturers in Sustainability Transitions

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Strategies of Incumbent Car Manufacturers in Sustainability Transitions

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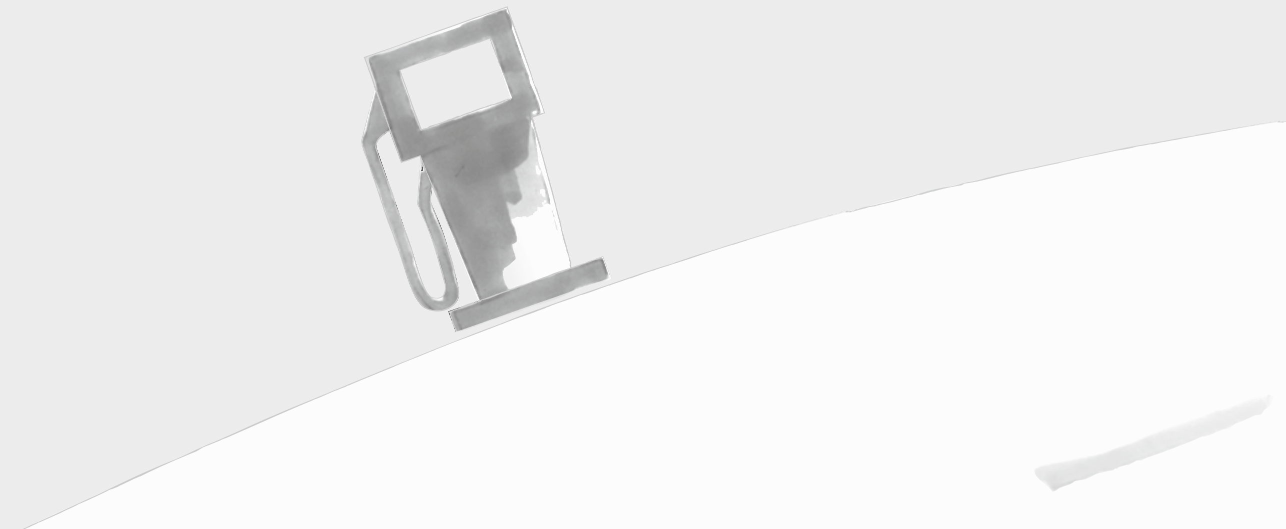


1 General introduction

1.1 The role of incumbent firms in sustainability transitions

Our society faces many sustainability problems, primarily because of its dependence on fossil fuels (UN, 1987). Burning of fossil fuels produces local air pollutants and greenhouse gases, of which CO2 is the largest contributor to climate change (IPCC, 2013). Increasing greenhouse gas and aerosol emissions are leading to a warming of the climate system, which causes extreme weather conditions and rising sea levels (IPCC, 2013). CO2 emissions are expected to increase by 46% between 2010 and 2040 (IPCC, 2007), while local air pollutions are causing severe smog problems in continuously expanding cities. Furthermore, many Western countries are dependent on oil imports, of which some 40% comes from politically unstable countries (EIA, 2013). Hence, security of supply is a problem, as political unrest in several oil producing nations persists, leading to increasing oil prices (EIA, 2013). The International Energy Outlook projects a 58% growth in energy consumption between 2010 and 2040, 80% of which is supplied by fossil fuels, meaning that sustainability will become an even bigger issue in the future (EIA, 2013).

Effectively addressing large scale sustainability problems requires deep structural changes in the socio-technical regime (Geels, 2011). Regimes entail established practices and associated rules that stabilize configurations of interacting dimensions, including technology, markets, industry, politics, culture, and science (Geels, 2002; 2011; Kemp et al., 1998; Grin et al., 2010). Regime actors reproduce and stabilize the regime that supports the established technology; they include firms along the value-chain, knowledge institutes, governmental bodies and consumers. Niches on the other hand are 'incubation rooms', protected from main stream market selection, were small networks of dedicated niche actors attempt to align socio-technical dimensions in ways that support emerging technologies that deviate from existing regimes (Schot, 1998; Kemp et al., 1998; Geels, 2011). Deep-structural regime changes should be brought about by new, sustainable technologies and the co-evolution of markets, industry, discourse and policy, which requires all regime actors to change (Geels, 2011).

Sustainability transitions bring about three unique problems (Geels, 2011). Firstly, 'sustainability' is a collective good, causing free rider problems and prisoner's dilemmas. To account for this, negative externalities of fossil fuel combustion need to be internalized, for example through public policy, to create a level-playing field for sustainable technologies (Longo et al., 2008; Foxon and Pearson, 2008). Secondly, in terms of individual consumer benefits, established technologies frequently outperform sustainable solutions. Therefore, sustainable solutions are unlikely to overtake established technologies without public economic support (Foxon and Pearson, 2008). Thirdly, the sectors where sustainability transitions are most needed, like transport and energy, are dominated by large, powerful incumbent firms. These firms have a strong asset base and "their involvement might accelerate the breakthrough of environmental innovations if they support these innovations with their complementary assets and resources" (Geels, 2011, p.25). Other scholars argue however, that incumbents are unlikely to accelerate change, because they are less able to do so, and have interests vested in their existing profitable position that results from established technologies – something labeled the 'incumbent's curse' (Chandy and Tellis, 2000). This 'curse' suggests incumbents have incentive to employ their power to protect their established technologies from new, competing ones.

The transition studies literature argues that sustainable technologies are likely to fail without public policy that internalizes the negative externalities of established technologies and that creates economically favourable conditions for emerging, sustainable technologies (Raven, 2004; Schot and Geels, 2008; Loorbach, 2010; Rotmans et al., 2001). Even with the current policies for limiting fossil fuel use, worldwide energy-related CO2 emissions are expected to rise by 46% between 2010 and 2040 (EIA, 2013). Policy makers therefore need to make more extensive use of policy interventions to drive sustainability transitions. They use demand-pull policy to create economically favourable conditions for sustainable technologies, like tax incentives, subsidies and other benefits, and to internalize the negative externalities of polluting technologies, like CO2 taxes. To tackle the problem of incumbent firms' unwillingness to innovate, policy makers employ technology-forcing regulations like emission standards and mandating specific types of sustainable technologies.

The way incumbent firms respond to socio-technical transition and the accompanied regulatory pressures is an emerging topic (Geels, 2014; Wells and Nieuwenhuis, 2012). Recent studies show that powerful incumbents influence regime-niche interaction in different ways. Firstly, incumbents have been shown to protect their vested interests through use of socio-cultural strategies like framing to affect public opinion (Smink et al., 2013; 2014; Penna and Geels, 2014). Such framing is used to downplay or even contest upcoming issues that are at the core of transitions, like climate change. Additionally, framing is used to determine what the solutions to such issues should be (Smink et al., 2014; Geels, 2014).

Secondly, to protect their vested interests, powerful incumbents have a history of opposing regulations that force them to support socio-technical transition through radical innovation. In the automotive sector for example, incumbent car manufacturers have engaged in defensive political influence strategies that included actions like collusion, lobbying, litigation and grassroots mobilization to oppose regulation in the 1970s that required them to install catalytic converters in their cars (Doyle, 2000; Penna and Geels, 2012). In the oil sector, oil companies engaged in political influence using lobbying and other information tactics to oppose biofuel blending regulations issued in 2007 in the Netherlands (Smink et al., 2013). Even demand-pull initiatives like the German Feed-in Law for solar and wind energy were opposed, through lobbying and litigation, by incumbent utility firms (Jacobsson and Lauber, 2006; Stenzel and Frenzel, 2008). So, although policy interventions are necessary to drive sustainability transitions, these examples illustrate that powerful incumbent firms have acted against the implementation of such policy interventions and have thereby hampered sustainability transitions.

Thirdly, incumbents do not always (continue to) oppose sustainability transitions. Recently, some incumbents have started to support emerging, sustainable technologies. To illustrate, some incumbent car manufacturers are now exploiting plug-in electric vehicles (Cole, 2014; Pinske et al., 2014), some incumbent oil manufacturers are supporting biofuel initiatives (Negro, 2007), and some incumbent utilities are exploiting wind power (Stenzel and Frenzel, 2008). This is not to say that all incumbents are supporting sustainability transitions. Stenzel and Frenzel (2008) for example, identified incumbent utilities in the UK and Spain as the main drivers for a transition to wind power, while at the same time incumbent utilities in Germany were identified as a bottleneck to a wind-power transition because they were opposing demand-pull policy interventions that supported wind power.

In sum, recent studies show that incumbents may adopt socio-cultural, political and technological strategies to defend against and/or adapt to socio-technical transition processes. This means that powerful incumbents can have a large influence on the success and rate of sustainability transitions, as on the one hand they have the resources to develop and commercialize sustainable technologies, and on the other hand they have the means to oppose transition by hampering technological, political and social change (Geels, 2011; Smink et al., 2013). The lack of understanding of the role of incumbents in protecting the regime and particularly the lack of explicit attention for power and politics in this process is perceived as a major gap in the transition studies literature (Wells and Nieuwenhuis, 2012; Grin, 2012; Grin et al., 2011; Smith et al., 2005; Meadowcroft, 2011; Geels, 2014). Moreover, it remains largely unknown why some incumbents do radically innovate and others do not (Chandy and Tellis, 2000). To tackle these gaps in the literature, the goal of this dissertation is to longitudinally study the innovation strategies and political influence strategies of incumbent firms, to assess their possibly changing positive or negative role in sustainability transitions and to determine why some incumbents radically innovate and others do not.

1.2 Theoretical framework

1.2.1 Strategies of incumbents in socio-technical transitions

Because the strategies of incumbent firms faced by socio-technical transition have received little attention in transition studies literature (Geels, 2014), we turn to firm-level theoretical perspectives in economics and management literatures. We use these literatures to conceptualize the innovation and political influence strategies with which incumbents respond to sustainability transitions and to gain an understanding of what factors may influence this response.

To conceptualize incumbents' innovation strategies we build on the resource based view (RBV) (Barney, 1991; Wernerfelt, 1984). As will be discussed in the Section 1.2.2, the RBV perceives firms as possessing bundles of difficult to imitate resources and competences that enable them to earn above normal returns (Barney, 1991; Wernerfelt, 1984). Because these resources and competences are to some extend technology-specific, the RBV is a useful theoretical perspective to explain why incumbents would be unwilling or unable to engage in radical innovation. The RBV also provides useful conceptualizations of 'innovation strategies' (Lieberman and Montgomery, 1998) and a clear set of indicators to study firms' innovative capabilities in the field of (radically) new technologies (e.g. Teece et al., 1997).

However, the RBV does not take into account that firms are also able to influence their regulatory environment through political influence strategies. Political influence strategies are focal to the corporate political activities (CPA) literature (Hillman et al., 2009), a substream of the resource dependence theory (RDT) (Pfeffer and Salancik, 2003). The RDT argues that to survive, firms influence the different types of organizations that make up their environment (Pfeffer and Salancik, 2003; 1972). Within the RDT, the CPA literature – discussed in-depth in Section 1.2.5 – focusses on how firms influence policy makers to shape their regulatory environment in ways favorable to them (Baysinger, 1984; Hillman et al., 2004).

To establish a conceptual framework that incorporates both incumbents' innovation strategies and political influence strategies, we combine the RBV and CPA literature. Combining theoretical perspectives can be useful as theories "complement one another either by focusing on different organizational phenomena and problems, or by emphasizing different aspects of similar phenomena and problems" (Baum and Rowley, 2002, p.10). Moreover, the RBV and CPA literature form a compatible combination as they have similar perceptions of the role of resources (Oliver and Holzinger, 2008).

The remainder of this subchapter discusses the RBV and its implications for innovation strategies and explains how it relates to incumbents' tendency not to radically innovate. Subsequently, it turns to the RDT and more specifically the CPA literature, to discuss what political strategies firms may employ when trying to influence the public policy environment. Finally, Section 1.2.6 incorporates the innovation and political influence strategies of firms into one framework.

1.2.2 Resource based view and dynamic capabilities

The RBV centers on the idea that firms must acquire and control resources that are valuable, rare, inimitable and non-substitutable to develop the products demanded by the market and earn above normal returns (Barney, 1991; Wernerfelt, 1984). These resources are heterogeneously distributed among firms and differences in firms' resource endowments allow for generating a sustained resource-based competitive advantage (Newbert, 2007, p. 123). Different types of resources – frequently labeled assets – together make up the firm's asset position (Teece et al., 1997). These assets are often technology-specific, as different technologies may require different assets like knowledge and production facilities. Technological assets entail protected knowledge necessary for the development and application of an innovation (Pavitt, 1998). Infrastructural assets refer to the technologies necessary for infrastructure-dependent innovations to operate properly (Teece, 2006), like charging stations for electric vehicles. Complementary assets are crucial to profit from innovations and include, for example, distribution channels, marketing and manufacturing facilities (Pinkse and Kolk, 2010; Rothaermel, 2001). Finally, reputational assets result from the company's alignment with existing norms and values, which forms customers' perception of the company, like brand experience (Teece et al., 1997).

However a primary critique to the RBV is its rather static nature (Newbert, 2007; Priem and Butler, 2001). This critique is tackled by the concept of 'dynamic capabilities', introduced by Teece et al, (1997), to explain how firms can change their assets so that their value is retained when the firm's environment changes. Dynamic capabilities are defined as "the firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments" (Teece et al., 1997, p.516). So when the market suddenly demands cleaner products, firms require dynamic capabilities to integrate, build and reconfigure new combinations of assets that generate these cleaner products. In conclusion, the dynamic capabilities concept is useful for determining to what extend firms are able to change their asset position along with changes in their environment. The asset position in turn determines to what extend firms are able to innovate. However, firms need to make the strategic choice to engage in innovation. For this we move on to the literature on innovation strategies.

1.2.3 Innovation strategies

The most commonly used definition of strategy is provided by Chandler (1962), who defines strategy as "the determination of the basic long term goals and objectives and the adoption of courses of action and the allocation of resources necessary for carrying out goals" (p. 13). This definition is adopted as it clearly points out the two sides of strategy. On the one hand, there are the long term strategic goals of the firm that enable it to acquire sustained competitive advantage. On the other hand, there are the strategic actions that support this strategy and that require the allocation of assets (Markard and Truffer, 2008a). An innovation strategy is defined 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).

An innovation strategy outlines how the firm intends to exploit a new technology and is therefore, like the assets of a firm, technology-specific. Existing literature generally distinguishes three types of innovation strategies: first movers, quick followers and laggards (Robinson and Chiang, 2002). First movers intend to become mass-market pioneers and subsequently stay ahead of competitors through technological lead-time (Freeman and Soete, 1997; Golder and Tellis, 1993). Firms with a quick follower strategy leave the decision of exploiting a radical innovation open, until a first mover goes to the market. Quick followers attempt to avoid the costly mistakes made by first movers and quickly follow them onto the market (Freeman and Soete, 1997; Lieberman and Montgomery, 1998). Finally, laggards are less engaged in innovative activities and attempt to acquire rents from reducing overall costs by minimizing R&D; they enter the market last (Freeman and Soete, 1997; Jovanovic and MacDonald, 1994).

For a firm to engage in innovation, Swann (2009) argues that it requires both incentive and opportunity to innovate. A firm's incentive to innovate refers to its incentive to enhance competitiveness and increase market share through innovation (Swann, 2009, p. 218). Technological competition is an important stimulus to the incentive to innovate, as the threat of new entrants and expanding rivals, buyers and suppliers trigger firms to innovate (Klein, 1977; Utterback and Suárez, 1993). The opportunity to innovate is the ability of a firm to engage in successful innovation, which – besides generic assets – depends on the asset position a firm has built up in a particular technological field (Lieberman and Montgomery, 1998; Silverman, 1999). The incentive and opportunity to innovate is therefore, much like the firm's asset position, technology-specific. The opportunity to innovate indicates to what extend a firm is capable of, and limited to engaging in a specific innovation strategy (Kraaijenbrink et al., 2010), whereas the incentive to innovate relates to the firm's willingness to pursue this strategy. Public policy may trigger firms' incentive to innovate, e.g. through standards and taxes or tax incentives that affect some technologies over others, as well as firms' opportunities to innovate, e.g. through R&D subsidies.

1.2.4 The incumbents' curse

The incentive and opportunity for a firm to innovate depend on the type of innovation. Radical innovations refer to innovations that overturn core concepts as well as the linkages between core concepts and components (Hall and Kerr, 2003; Afuah and Bahram, 1995). Depending on the firm's position in the value-added chain, such innovations render obsolete the incumbents' existing technology-specific assets and competences (Hall and Kerr, 2003). Incumbents have little incentive to contribute to rendering obsolete their core competences and cannibalize upon their own profitable products by engaging in radical innovation (Ali, 1994; Reinganum, 1983). Moreover, they may not be able to do so because they may lack the necessary assets (Nelson and Winter, 1982; Henderson, 1993; Ghemawat, 1991), or because they are unable to exploit new business cases and value networks (Christensen, 1997; Rosenbloom and Christensen, 1994). Consequently, the firm's core competences become 'core rigidities' (Leonard-Barton, 1992), which is why studies find that incumbents often lose when faced with radical innovation, something that is labelled the incumbents' curse (Chandy and Tellis, 2000).

However, the incumbents' curse has been challenged by Chandy and Tellis (2000) and Lepore (2014), who argue that some incumbents do radically innovate and that incumbents do not necessarily perish when they 'lose'. Indeed, incumbents have been found to engage in radical innovation in the automotive sector (Cole, 2014), the oil sector (Suurs, 2009) and the electricity sector (Stenzel and Frenzel, 2008). Building on the debate about incumbents' tendency (not) to radically innovate, we believe it is time to stop perceiving of 'incumbents' as a homogeneous pool of firms, and start looking into the firm-level differences that may explain why some incumbents do radically innovate and others do not.

1.2.5 Resource dependence theory: political influence through corporate political activities

The RDT suggests that to survive, firms influence the different types of organizations that make up their environment (Pfeffer and Salancik, 2003; 1972). They do so in different ways; they may increase control over organizations in their environment by increasing their power through growth; they may absorb the organizations on which they are dependent or form partnerships with them; they may diversify to spread risks; and they may engage in political action to manage dependencies and uncertainties resulting from the regulatory environment (Van Mossel et al., 2014; Pfeffer and Salancik, 2003). Embedded within the RDT, the CPA literature aims to develop an understanding of how firms are able to influence their regulatory environment (Hillman et al., 2009).

CPAs are defined as "corporate attempts to shape government policy in ways favorable to the firm" (Hillman et al., 2004, p. 838; Baysinger, 1984) and include actions like lobbying, litigation, financial contributions, constituency building and utilizing political networks. The CPA literature argues that in strongly regulated environments, firms may strengthen their competitive advantage by engaging in political influence strategies (Hillman and Hitt, 1999; Oliver and Holzinger, 2008). Political influence strategies are "firm-level actions undertaken for the purpose of mobilizing support for the firm's interests" (Oliver and Holzinger, 2008, p.505). Consequently, 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 the value of their asset position, or to create new value (Hillman and Hitt, 1999; Lux et al., 2011; Oliver and Holzinger, 2008; Buysse and Verbeke, 2003).

Incumbents with political influence strategies utilize CPAs to shape regulations that support sustainability transitions, either to maintain value in a defensive political strategy, or to create value in a proactive strategy. Firms engaging in defensive political influence strategies oppose regulations that threaten their firm's value, like technology-forcing regulations supporting sustainability transitions, and try to maintain the favorable status quo (Schaffer et al., 2000; Oliver and Holzinger, 2008; Stenzel and Frenzel, 2008; Hillman et al., 2004; Carroll, 1979). Proactive political influence strategies are intended to shape regulations in order to support the firm's innovation strategies that aim to create new value (Carroll, 1979; Buysse and Verbeke, 2003; Oliver and Holzinger, 2008). While defensive strategies oppose change in the policy dimension of the regime, often to the detriment of a sustainability transition, proactive strategies may support such policy change to the benefit of a transition.

Firms can choose to engage in political influence individually or collectively (Hillman et al., 2004; Hillman and Hitt, 1999; Olson, 1965; Yoffie, 1987; Bonardi et al. 2005). Industry associations and other lobbying coalitions are collective groups that represent the interests of their members by engaging in political strategies. The main advantages of collective action include reduced cost per firm and the potential for enhanced success as actions are supported by a larger group and therefore carry more weight (Chong, 1991; Jia, 2014; Olson, 1965; Vining et al., 2005). Hillman and Hitt (1999) noted that when it comes to opposing sensitive policy issues, like climate change and public health, collective actions can also limit the exposure and liability of members when coalitions lose a political battle. A disadvantage of collective action is that the individual firm is less able to influence policy to meet its specific individual needs (Hillman and Hitt, 1999; Jia, 2014; Vining et al., 2005).

Although political influence strategies have been extensively studied within the CPA literature, it has less frequently been applied in the context of socio-technical transition. Additionally, within CPA literature the "least complete understandings revolve around the ways that CPA changes over time" (Getz, 1997, p.64). It is therefore worthwhile to study whether incumbents over time have changed their political influence strategies regarding regulations that support the transition towards a more sustainable mobility system.

1.2.6 Innovation and political influence strategies in response to regulatory change

To summarize, firms may respond in two, possibly complementary ways to public policy that favors new sustainable technologies: through innovation to comply with or exploit the public policy and/or through political influence to influence the policy. The type of public policy issued by policy makers to support new sustainable technologies is likely to affect the strategic response of incumbent firms. Policy makers may create opportunities for firms to develop new sustainable technologies, for example through policies like subsidies, patent provision and research grants. Alternatively, policy makers may create opportunities for firms to commercially exploit sustainable technologies by issuing demand-pull initiatives that benefit sustainable technologies, like tax incentives, government purchases and tariff protection. Incumbents may be less inclined to engage in defensive political influence towards such rewarding public policy. However, policy makers may also penalize unsustainable technologies, for example through carbon taxes, or force sustainable technologies onto the market by capping emissions, issuing low carbon standards or forcing new sustainable technologies onto the market. Because such penalizing and forceful regulations directly threaten the existing business cases of incumbents, incumbents are more likely to act defensively. When regulations force incumbents to engage in innovation, compliance strategies (Oliver and Holzinger, 2008) have to be innovation strategies. Hence, the link between innovation and political influence strategies is the strongest under such technology-forcing regulations.

Building on the conceptual framework by Oliver and Holzinger (2008), we create a conceptual framework on corporate response strategies to public policy that favors new sustainable technologies, see Table 1.1. This framework distinguishes not only between innovation and political influence, but also between value maintenance and value creation. Consistent with the RBV, we refer to value maintenance as "the preservation of those firm assets and competences that constitute the foundation of firm rents", and to value creation as "the invention or reconfiguration of firm assets or competences that constitute an original or unique addition to firm rents" (Oliver and Holzinger, 2008, p. 497). Although all innovation strategies generally create new value, it is possible to distinguish between reactive and anticipatory strategies. Anticipatory innovation strategies anticipate public policies in which new technologies will be favored or forced onto the market. These strategies create value by trying to exploit early mover advantages in these technological fields (Oliver and Holzinger, 2008). As such, they resemble the stronger first mover and quick follower innovation strategies (Lieberman and Montgomery, 1998). Reactive innovation strategies focus on cost-efficient compliance with regulations and remain flexible to quickly meet political demands (Oliver and Holzinger, 2008). This includes laggard innovation strategies, where firms try to maintain the value of existing technology and related assets as long as possible and minimize R&D costs by efficient adaptation (Lieberman and Montgomery, 1998).

The previously discussed defensive political influence strategies are of a value maintaining nature, as they aim to protect the status-quo, whereas the proactive political influence strategies aim to shape policy to create new value for the firm and are therefore of a value creating nature.

Table 1.1: Response strategies to public policy that favors innovation, comprising innovation and political influence strategies, adapted from Oliver and Holzinger (2008)

		Value perspective	
		Value maintenance	**Value creation**
Strategic orientation	**Innovation**	**Reactive innovation strategy** *Cost-efficient compliance with public policy through laggard innovation strategies.*	**Anticipatory innovation strategy** *Anticipate public policy on new technologies and stay ahead of policy changes through first mover and quick follower innovation strategies.*
	Political influence	**Defensive strategy** *Engage in political influence to oppose change in public policy.*	**Proactive strategy** *Engage in political influence to shape public policy to gain competitive advantage.*

Factors related to competition, such as the threat of new entrants and expanding rivals, buyers and suppliers, triggers firms to engage in innovation and adopt more value creating strategies (Klein, 1977; Utterback and Suárez, 1993). Similarly, firms with strong incentive and opportunity to innovate are expected to adopt more value creating strategies (Swann, 2007).

The above conceptual framework can be used to study previously unaddressed research questions that are particularly relevant to the field of transition studies, the RBV and the CPA literature, such as 'Why do some incumbents radically innovate and others not?'; 'How do firms combine innovation and political influence strategies when faced with policy interventions that favor certain technologies over others?'; 'How do these possible combinations of strategies change over time?'.

1.3 Case selection

To study the innovation and political influence strategies of powerful incumbents in sustainability transitions in-depth, this dissertation focuses on a particular selection of incumbents. Such focus enables the study all aspects of their strategies, which is important to identify the multifaceted role of incumbents in transitions and how their strategies are interconnected and change over time. The generalizability of the findings to other types of powerful incumbents and other sectors requires testing in future research.

The focal incumbents are car manufacturers. Their strategies regarding clean vehicle technologies (CVTs) are studied, as passenger cars emit 12% of the EU's total CO_2 emissions (EC, 2007), contribute significantly to smog problems (Uherek et al., 2010) and because "some of the greatest potential for altering the growth path of energy use is in the transportation sector"; a potential that can be fulfilled through more stringent policy interventions (EIA, 2013, p.2). Moreover, despite rising fuel prices, increased demand for liquid fuels for transportation, primarily by non-OECD economies, is projected to increase consumption by 38% from 2010 to 2040 (EIA, 2013). This will put tremendous strain on the oil supply which has not risen since 2005 to meet increased demand (Murray and King, 2012). Hence, the transition to more fuel efficient and alternative CVTs is very important, and this case study therefore also serves a practical purpose.

However, the internal combustion engine (ICE) that causes these emissions and society's dependence on oil, has been the established technology for over a hundred years (Mom, 2004). This means that many powerful incumbent car manufacturers derive their profitable position from this technology. To protect their profitable position, they are incentivized to oppose the new CVTs that threaten to overtake the ICE technology. CVTs comprise low emission vehicle (LEV) technologies and zero emission vehicle (ZEV) technologies. LEVs include hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) that have lower emissions than ICEVs due to their partial electric drive train which allows for storage of breaking energy and, in the case of PHEVs, external charging. However, ZEVs like full-electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs) that are completely independent from petrol and have zero tailpipe emissions, build on completely new technologies and would therefore render obsolete the ICE-based competences built up by incumbent car manufacturers. In other words, these are radical innovations for incumbent car manufacturers, because all ICE components are being replaced by new components for the EV or HFCV. Not only are the key components replaced, the linkages between them are also different (Afuah and Bahram, 1995, p.59). Because LEVs to some extent build on the ICE technology, whereas ZEVs do not, LEVs pose less of a threat to the competitive advantage of incumbent car manufacturers than ZEVs do; car manufacturers therefore have a little more incentive to innovate in LEVs than ZEVs. Not surprisingly, car manufacturers have a history of opposing policy interventions that make them produce CVTs (e.g. Boschert et al., 2006; Doyle, 2000; Penna and Geels, 2013).

Nevertheless, some incumbent car manufacturers are currently commercializing EVs (Cole, 2014), suggesting that they have pursued strong innovation strategies in the field of ZEVs. This apparent contradictory behavior provides a good case study to further explore how different car manufacturers have combined innovation and political influence strategies over time, in the field of CVTs.

To study political influence strategies, we focus on technology-forcing regulation, because the link between innovation and political influence strategies is the strongest under such regulations. More specifically, we study the case of the Californian ZEV mandate over the timeframe 1990-2013. This mandate forces CVTs onto the market, including the above mentioned HEVs, PHEVs, EVs and HFCVs, with the goal of making the currently unsustainable automotive 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 has been adapted through various rulemakings, during which industry was able to influence the policy making process. Moreover, the mandate can be seen as an internationally very influential policy intervention, as it is adopted by California – one of the largest car markets in world, and by nine other US states (CARB, 2012). Various CVTs started emerging when the ZEV mandate was implemented. The ZEV mandate over the timeframe 1990-2013 therefore constitutes a good case to longitudinally study the interrelations between, and possible changes in corporate innovation and political influence strategies in response to influential policy that forces sustainable technologies onto the market.

1.4 Research questions and research outline

The goal of this dissertation is to understand the strategies of powerful incumbent firms in sustainability transitions, from a firm-level theoretical perspective embedded within the resource-based and resource-dependent view. It is important to know why some incumbents radically innovate and others do not, and how incumbent firms combine innovation and political influence strategies in response to policy interventions that aim to force sustainable technologies onto the market. Moreover, it is important to know if, when and why incumbents' strategies change. Because of increasing pressure by public policy, sustainable entrepreneurs, and increasing demand, incumbents are driven to radically innovate in the field of sustainable technologies. Hence, a shift from value maintaining strategies towards value creating strategies may be expected, as incumbents succumb to these increasing socio-technical transition pressures.

Insights in the response strategies of incumbents towards socio-technical transition pressures, particularly public policy pressures, are important for researchers and policy makers to understand how firm-level strategies may significantly affect the rate of sustainability transitions. Understanding such firm-level strategies not only furthers the academic field of transition studies, but may help policy makers craft more effective policy, specifically geared to changing the strategies of powerful incumbent firms from value maintaining strategies that oppose, to value creating strategies that support sustainability transitions. The main research question of this dissertation is: **What explains the expected dynamics in innovation and political influence strategies of incumbent car manufacturers in the field of clean vehicle technologies, over the period 1990-2013?**

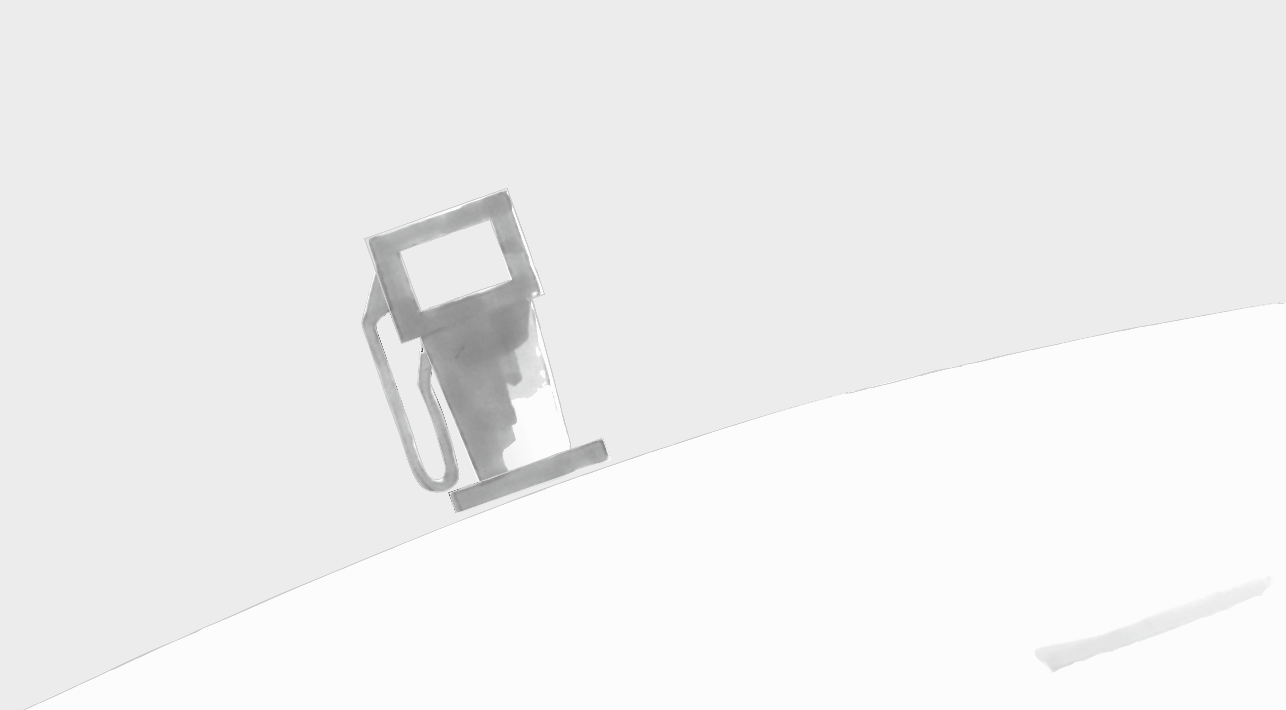
Because competitive forces are known to stimulate innovative behaviour of firms, we study in Chapter 2 how different competition-related forces stimulate innovation in CVTs. To determine what types of incumbents engage in radical innovation, Chapter 3 studies how incentive and opportunity to innovate affect the decision to radically innovate in the field of EVs. To gain more insight in the (changing) political strategies of incumbents, Chapter 4 focuses on the political strategies of incumbent car manufacturers and their coalitions regarding the ZEV mandate over the period 2000-2013. Finally, in Chapter 5 we combine and complement all previously collected data to comprehensively analyse the strategies of incumbents in response to the ZEV mandate over the period 1990-2013. We distinguish in these strategies on the one hand between value creation and value maintenance, and the other hand between innovation and political influence strategies. The competition-related forces and incentive and opportunity to innovate studied in Chapters 2 and 3 are expected to drive incumbents to adopt more value creating innovation and political influence strategies. To answer our main research question, this dissertation builds on a database comprising patents and sales data to measure the R&D and commercialization component of incumbents' innovation strategies and uses content analysis of public documents and interviews to measure political influence strategies.

In Chapter 2 of this dissertation the continuation of waves of technological development of CVTs are studied. Waves of technological development are the result of increases and subsequent decreases in R&D investments, caused by firms' shifting R&D strategies that are based on their changing expectations regarding emerging technologies. In the period 1990-2011, the automotive sector has known four waves of development of CVTs. Two of these waves were broken before becoming a commercial success, one was continued, and one is the current wave of EV development. This chapter establishes a set of competition-related factors that are hypothesized to increase the length of waves of technological development (Frenken et al., 2004; Klein, 1977; Utterback and Suárez, 1993), including rivalry, dispersion and the presence of new entrants. We study how these factors influence the continuation of waves of technological development. Using this set, it may be predicted whether the current wave of EV development will be continued, or will break as some previous waves did. The research question of this chapter is: **How did the forces of rivalry, dispersion and the presence of new entrants affect the duration of earlier waves of CVT development and how do these competitive forces affect the chances of continuation of the current wave of EV development?**

In Chapter 3 we study how the incentive and opportunity to innovate may explain why some incumbent car manufacturers do and others do not radically innovate in the field of EVs. The tendency of incumbents to radically innovate has been extensively debated (Chandy and Tellis, 2000; Lepore, 2014). The incumbent's incentive to innovate is measured by its profit in the field of the established ICEV technology, since it may be expected that incumbents profiting a lot from the established technology have little incentive to overthrow their own profitable position through radical innovation. The incumbent's opportunity to innovate is approached by the assets the firm had developed to exploit EVs. The concepts of incentive and opportunity are used to gain more insight in incumbents' innovation strategies in the field of EVs. Based on the focal incumbent's timing of EV commercialization, we distinguish between first mover, quick follower and laggard innovation strategies. Understanding why some incumbents radically innovate and others do not will enrich the discussion on incumbents' tendency to radically innovate. The research question addressed in this chapter is: **How did the incentive and opportunity to innovate affect incumbent car manufacturers' decision to mass market EVs over the period 1990–2011?**

In Chapter 4 of this dissertation we study if and how incumbent car manufacturers and their political coalitions changed their political strategies with respect to policy interventions that support sustainability transitions. The longitudinal case study focuses on incumbents' responses to the Californian ZEV mandate, over the period 2000-2013. As explained in the Case Selection Section, this regulation mandated the sales of CVTs like HEVs, PHEVs, EVs and HFCVs. We used the CPA literature to conceptualize political strategies, the tactics underlying these strategies and the actions through which firms respond to policy interventions. Within the CPA literature the "least complete understandings revolve around the ways that CPA changes over time" (Getz, 1997, p.64); studying these changes in political strategies over time thus provides a valuable addition to the literature. It also provides important insights in the way powerful incumbents may inhibit or accelerate sustainability transitions by influencing the regime's policy dimension. We study in this chapter not only the political strategies of individual incumbents, but also the political strategies of their political coalitions, e.g. industry associations. Firms generally use these coalitions to do their 'dirty work', as coalitions suffer less from the image penalties of such work than individual firms. The research question addressed in this chapter is: **What were the political strategies employed by incumbent car manufacturers and their political coalitions in response to the ZEV mandate, over the period 2000-2013?**

In Chapter 5 we study how car manufacturers combine and change their innovation strategies in the field of CVTs and their political influence strategies, in response to the ZEV mandate over the period 1990-2013. The interaction between innovation and political strategies has received little attention. Although studies like Levy and Rothernberg (2002) and Stenzel and Frenzel (2008) have included both firms' innovation and political influence strategies, they have not focused on their interaction and potential change over time. Although strategic change remains largely unexplored, it is very relevant in the context of sustainability transitions, as incumbents are expected to change their innovation and political strategies as socio-technical transition pressures increase over time. This chapter provides an important contribution to both innovation and political influence literatures by focusing on the interaction between and change in innovation and political influence strategies over time. These literatures are integrated through our conceptual framework that, building on Oliver and Holzinger (2008), incorporates both innovation strategies and political influence strategies. This chapter combines and builds on the data of the previous chapters to comprehensively study the role of individual car manufacturers in the transition to a more sustainable automotive transportation system. The research question of this chapter is: **How have incumbent car manufacturers combined and changed their innovation and political influence strategies in response to the ZEV mandate, over the period 1990-2013?**



2 How competitive forces sustain electric vehicle development

Abstract

This patent study researches the relation between competitive forces and the continuation of waves of Clean Vehicle Technology (CVT) development. The competitive forces included are rivalry, dispersion referring to competition in general, and the presence of new entrants. We identify four waves of CVT development over the past 21 years, two of which were broken before becoming a commercial success, one that was continued, and the current wave of electric vehicle (EV) development. Although the presence of new entrants could not be tested for all cases, our findings suggest that the combination of rivalry and dispersion positively relates to continued CVT development. We conclude that continuation of the current wave of EV development is likely, as it is supported by increases in rivalry, dispersion and the presence of new entrants.

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2.1 Introduction

In the mobility system, emissions from internal combustion engine vehicles (ICEV) have significant impacts on climate change and on the atmosphere, e.g. through smog formation (Uherek et al., 2010). It is therefore important that the mobility system becomes more sustainable. Within the portfolio of technologies necessary to attain a sustainable mobility system, Clean Vehicle Technologies (CVTs) , such as the Electric Vehicle (EV), the Hydrogen Fuel Cell Vehicle (HFCV), and the Hybrid Electric Vehicle (HEV), present a good alternative to the established ICEV (Tukker, 2005). Although technological development might make ICEVs increasingly lower-emission vehicles, this chapter focuses on the previously mentioned three types of CVTs. Each of these CVTs contains a partial or full electric drivetrain and constitutes a technology that is significantly different from the established ICEV. These solutions have gained increasing attention and are becoming ever better developed (Oltra and Saint Jean, 2009; IEA, 2011).

Competence-destroying CVTs like the EV and HFCV that render obsolete the established ICEV technology (Tushman and Anderson, 1986) have enjoyed a trend of increasing attention and decades of technological development (Hoyer, 2007; Frenken et al., 2004), in spite of which they have not experienced commercial success. This is on the one hand due to the established ICEV, which automotive firms have continuously developed to become cheaper and more sustainable (Oltra and Saint Jean, 2009). On the other hand, however, the failure of these competence-destroying CVTs can be explained by their pattern of development, which has always been characterized by hypes: periods of increased optimism succeeded by periods of disappointment. In this chapter we focus on hypes to explain the presence and absence of CVTs' commercial success. We refer to the periods of increased technological development that accompany these hypes as 'waves of CVT development'. Waves of development are broken due to a successive period of disappointment (Van Lente, 1993). A notable exception is the HEV. The technology is less competence-destroying and the wave of development is continued, leading to actual diffusion of this technology in the market and commercial success (Pohl and Yarime, 2012).

Another wave of CVT development recently emerged. After the high hopes for hydrogen as a fuel plummeted in the last 5 years, the new hope of the automotive sector seems to be the EV. Several car manufacturers are testing EVs and investment decisions have been made to build factories. But it is uncertain whether this is just another hype that will be accompanied by disillusion in the near future, or whether this wave of technological development will actually become a continued one that may lead to commercial success.

To assess the chances of success of a new technology, in most cases technological characteristics and price developments are used. In earlier hypes of CVTs we witnessed intense disagreement between technological experts on expected technological performance and price developments (Bakker et al., 2012a; Mom, 2004). Therefore, in this study we take another approach. We assess how the industry structure develops around emerging CVTs. Ceteris paribus, our basic assumption is that when an increased number and higher diversity of firms move into a new trajectory leading to more technological competition, the new technology is more likely to be continuously developed, improving its chances of commercial success. This relation between competition and innovation draws on an extensive body of literature that describes a positive relation between competition and continued technological development (Klein, 1977; Utterback and Suárez, 1993). Literature shows that this also applies to CVT development (Pohl and Yarime, 2012; Van den Hoed, 2005; Dijk and Yarime, 2010).

These competitive forces can be broken down into different dimensions. It is important to distinguish 1) the level of rivalry between car manufacturers, 2) the level of dispersion: the extent to which different types of organizations contribute to technological development and 3) the presence of new entrants. This unprecedented set of dimensions draws from Technology Life Cycle literature (Utterback and Suárez, 1993) and builds on previous CVT studies (Pilkington and Dyerson, 2006).

In this article we first test whether the presumed positive correlations between these forces and continued technological development hold for three waves of technological CVT development. Subsequently, we analyze how these competitive forces relate to the fourth and current wave of EV development to assess if continued technological development is now more likely to occur than during previous waves. Consequently, our research question is as follows: "How did the forces of rivalry, dispersion and the presence of new entrants affect the duration of earlier waves of CVT development and how do these competitive forces affect the chances of continuation of the current wave of EV development?"

In this chapter we study the relationship between competitive forces and waves of CVT development through patents. We analyze the technological fields of EV, HEV and HFCV. In this patent study we intend to make four additions to the existing literature. Three are related to the literature on CVT forecasting and one to the general literature on technological forecasting.

- First, the timeframe of study comprises the period 1990-2010, enabling us to study the contemporary wave of EV development that falls outside the timeframe of most previous studies (Oltra and Saint Jean, 2009; Frenken et al., 2004; van den Hoed, 2005).

- Second, we relate CVT development to a set of competitive forces not studied before and in doing so we broaden the scope of research outside the frequently studied population of large car manufacturers (Oltra and Saint Jean, 2009; Frenken et al., 2004; van den Hoed, 2005).

- Third, we not only use the conventional search queries applied in previous studies, but add search queries on the component level of a CVT to enhance the capture of relevant patents, which results in a more comprehensive study of technology development.

- Fourth, we develop a set of indicators that are useful for technological forecasting. Until now, very little attention has been given in forecasting literature to using data on technological competition in order to assess future technological developments.

The remainder of this chapter is structured as follows. In section 2 we first elaborate on the waves of CVT development in the period 1990-2010 and subsequently describe how the competitive forces positively influence continuation of waves of CVT development. In the subsequent methodology section we elaborate on the research design and methods of data collection and analysis. We present the results and analysis in section 4. Finally, in section 5 we provide some conclusions, a discussion and some recommendations for further research.

2.2 Theoretical framework

This study on waves of technological development lies embedded within the larger body of literature that focuses on technological change. Perhaps the most well-known theoretical model is the Product Life Cycle (PLC), which is intertwined with industry and technology life cycles (Tushman and Anderson, 1986; Klepper, 1996; Abernathy and Utterback, 1978). The PLC describes a cyclical process of transition were a radical innovation introduces an era of ferment, which is ended by the emergence of a dominant design that initiates an era of incremental innovation, which in turn is ended by the next radical innovation (Tushman and Anderson, 1986; Klepper, 1996; Abernathy and Utterback, 1978). In the automotive sector, research shows that the CVTs under study are still in the era of ferment (Pohl and Yarime, 2012; Sierzchula et al., 2012a), whereas the ICEV has been the mature technology that was improved by incremental innovation for decades. Our study on waves of CVT development lies embedded within the PLC's era of ferment, which so far left these development dynamics largely unaccounted for. The PLC stresses that competitive forces play an important role in facilitating the development of emerging technologies like CVTs, especially in their era of ferment (Tushman and Anderson, 1986; Klepper, 1996; Abernathy and Utterback, 1978). Consequently, in this theory section we discuss the relation between waves of technological development and a set of competitive forces to make predictions about the continuation of these waves of development.

2.2.1 Waves of development

The period 1990-2010 experienced four waves of CVT development. The first wave concerns the broken wave of EV development in the early nineties (Kemp, 2005; Bakker, 2010) and was initiated by the demonstration of GM's working EV prototype, the EV1. Other large car manufacturers quickly followed GM with increased investments in EV development and assembled their own working EV prototypes (Kemp, 2005; Collantes and Sperling, 2008). However, this period was followed by a period of disappointment. High costs and low range were reported as technological showstoppers. The second broken wave comprised the development of HFCVs from the late 1990s to the mid-2000s (Van den Hoed, 2005; Bakker, 2010). This wave was initiated by Daimler moving first into HFCV development, and other car manufacturers followed quickly (Van den Hoed, 2005; Bakker, 2010). Reasons for the crumbling belief in this option were high costs for fuel cells and infrastructure problems. Third was the continued wave of HEV development that started in the late nineties and led to commercial success. This wave was pioneered by Toyota and Honda, who brought HEVs to market in 1997 and 1998 respectively (Magnusson and Berggren, 2011). Triggered by high sales, various other car manufacturers invested in HEV development and marketed their own vehicles starting in 2006, which further increased commercial success (Dijk and Yarime, 2010; Chanaron and Teske, 2007). A fourth wave concerns the EV development that started in approximately 2006 (Sierzchula et al., 2012). This wave was different from previously discussed waves in the sense that new entrants reportedly played an important role in triggering it: numerous new entrants began producing EVs from 2006 onwards, whereas most incumbent car manufacturers did not introduce their own prototype or production vehicles until 2009 (Sierzchula et al., 2012a). Since the automotive sector actively uses patents to protect intellectual property, the previously discussed four waves of CVT development should be reflected in patent data. Hence the following proposition:

Proposition 1: Waves of CVT development identified in previous studies are characterized by technological progress and therefore reflected by peaks in patent data.

2.2.2 Competitive forces that influence continuation of waves of technological development

Competitive forces have been studied extensively in relation to technological development (Pohl and Yarime, 2012; Klein, 1977; Utterback and Suárez, 1993). Already in 1993 Utterback and Suárez (1993, p.1) wrote that "greater degrees of competition will result in more rapid rates of technological change". Below, we discuss three competitive forces and pressures to innovate that are found to be important for the continuation of technological development.

Rivalry
Rivalry takes place between established firms active in the same product market within a specific CVT field, for example between established car manufacturers. Rivals tend to compete especially through incremental innovation (Nelson and Winter, 1982). The positive effect of rivalry on technological development of CVTs has frequently been confirmed for rival car manufacturers. For example, Van den Hoed (2005, p.269) finds in his study on the commitment of car manufacturers to HFCV development that "[rivalry] forces play an important role for carmakers to invest considerably in these alternative [CVT] technologies … although belief in these technologies may lack, companies still engage in these technologies in order not to lag behind". The same is found by Pohl and Yarime (2012, p.11), who identified "intense competition, mainly between Toyota and Honda, as a crucial factor for the development in the [HEV and EV] domain since the mid-1990s". Others (Dijk and Yarime, 2010; Chanaron and Tekse, 2007) stress that successful HEV development in turn triggered other firms to enter the field and contribute to further technological development. These and other studies (e.g. Magunusson and Berggren (2011) and Van Bree (2010)) highlight that it is especially the interplay between rivalry and technological development that supported continued CVT development in the period 1990-2010. According to life cycle literature, rivalry becomes an especially strong force when the technology matures and enters an era of incremental innovation (Tushman and Anderson, 1986). The relation between rivalry and continued technological development is captured in the following proposition:

Proposition 2: Increasing rivalry is positively related to continued waves of CVT development.

Dispersion
Large car manufacturers have been an important subject of studies on CVT development, which is justified by the fact that these firms make the largest contributions to CVT development (Oltra and Saint Jean, 2009; Frenken et al., 2004; Pohl and Yarime, 2012; Van den Hoed, 2005). However, there are also other firms that make important contributions. These firms include not only different tier suppliers (Kemp, 2005), but also research institutes, providers of infrastructure and services and other organizations involved in CVTs. Dispersion refers to the extent to which different types of organizations contribute to technological development.

Increasing dispersion is expected to be positively related to continuation of waves of CVT development for several reasons. First, the more firms support a wave of CVT development, the less vulnerable this wave becomes to the disruptive effect of individual firms withdrawing their support for the wave of development. Second, when there are more firms active in the development of CVTs there is more competition, not only between car manufacturers as in the case of rivalry, but also between other firms that compete within and across (vertical integration) any segment of an CVT value chain. Stronger competition over the entire value chain triggers increased technological development by any firm in the value chain (instead of only by car manufacturers as in the case of rivalry). The relation between dispersion and continued technological development is captured by the following proposition:

Proposition 3: Increasing technological dispersion is positively related to continued waves of CVT development.

Presence of new entrants

Tushman and Anderson (1986) stress that the contribution of new entrants to technological development is especially strong in the field of a competence-destroying technology; especially during an era of ferment. Competence-destroying technologies render obsolete the competences required to profit from existing technology, in the same way that the EV and HFCV render obsolete some competences required to profit from the ICEV. Development of competence destroying technologies like the EV and HFCV lower entry barriers and open up windows of opportunity for new entrants to enter the market (Tushman and Anderson, 1986; Utterback and Suárez, 1993; Abernathy and Utterback, 1978; Blees et al., 2003; Jovanovic and MacDonald, 1994). New entrants include not only startups but also diversifying established firms moving into new markets (Utterback and Suárez, 1993). Once new entrants have entered the market, they themselves engage in technological development through the exploitation of novel combinations of related technological fields, thereby boosting technological development (Schumpeter, 1936). Additionally, the presence of new entrants also triggers established firms to engage in development of the competence-destroying technology: the so-called 'incumbent challenger dynamics' (Ansari and Krop, 2012). Through these dynamics and the continuous influx of new entrants caused by technological development, technological development becomes continued:

Proposition 4: Stronger presence of new entrants is positively related to continued waves of competence-destroying CVT development.

Finally, the previously related competitive forces are also related to each other. Technological development triggers not only rival car manufacturers to enter a technological field and engage in development, but also firms in other product segments and especially new entrants. Through the previously described mechanisms of increased rivalry, dispersion and the presence of new entrants, technological development is expected to be continued. However, it is possible that technological development might trigger only one factor, and inhibit others. For example, when technological development triggers strong rivalry amongst car manufacturers, which consequently dominate the technological field and cause vertical integration, this might induce entry barriers for firms in other product segments and for new entrants coming from other sectors or startups. Consequently, dispersion and the presence of new entrants might be inhibited at the cost of increased rivalry. In such instances, the positive effects of one force might be undone by the negative effects of other forces. In such cases, it would be interesting to identify any dominance of one factor over the others. We make no predictions about the consequences of such instances for continued technological development, but only propose that when all forces increase, this will lead to continued CVT development.

2.3 Methodology

In this methodology section we first discuss the selection of patents as an indicator for technological CVT development. Second, we present the research design and data collection, including an elaboration on the search queries we constructed. Subsequently, we describe the operationalization of indicators used to study the proposition described in the previous section.

2.3.1 Selection of the indicator of technological development

Various indicators have been used to study CVT development, including media statements (Bakker, 2010; van den Hoed, 2004), prototypes (Magnusson and Berggren, 2011; Bakker et al., 2012b), production models and sales figures (Dijk and Yarime, 2010; Chanaron and Teske, 2007), and patents (Oltra and Saint Jean, 2009; Frenken et al., 2004). However, not all of them are accurate as an indicator for actual technological development over time and to measure the competitive forces.

Prototypes, production models and car sales primarily reflect the technological development by car manufacturers and not of other firms, which we intended to include in our analysis through the measure of dispersion. Additionally, production models and sales figures do not give a thorough picture of early stage R&D. Media statements and prototypes shown at auto shows serve as channels that enable car manufacturers to influence the perception of competitors, policy makers and the public regarding a certain type of CVT (Van den Hoed, 2004; Bakker, 2010). They can therefore be effective means to influence CVT specific competition, policy making and demand respectively, without reflecting actual technological development. Because of these potentially strategic purposes, media statements and prototypes are also less suitable indicators for actual technological development.

Patents, however, are used more for protecting internal intellectual property than for strategic positioning and influencing outsiders' perception. Therefore, they are a better indicator for R&D and actual technological development (Oltra and Saint Jean, 2009; Van den Hoed, 2005; Archibugi and Pianta, 1998) and are frequently applied in technological forecasting studies in related fields (Daim et al., 2006; Harell and Daim, 2009). Furthermore, patents are applied for by various types of organizations and therefore enabled the analysis of rivalry, dispersion and the presence of new entrants. Finally, patents are easily available in large quantities in long time series, thereby allowing comprehensive longitudinal analyses (Oltra and Saint Jean, 2009; Van den Hoed, 2005; Archibugi and Pianta, 1998). However, patents also have some drawbacks: the tendency to patent differs over time and between countries, sectors, firms and technologies (Oltra and Saint Jean, 2009; Van den Hoed, 2005; Archibugi and Pianta, 1998). We account for most of these differences by making relative instead of absolute comparisons. Unfortunately, like other patent studies, we could not account for firm level differences as a result of different Intellectual Property Rights strategies. Despite this setback, patents provide the most suitable indicator for this study.

2.3.2 Research design and data collection

As stated in the introduction, in this study we first investigated the presumed positive relations between on the one hand rivalry, dispersion and the presence of new entrants and on the other hand broken and continued waves of CVT development. The early wave of EV development and the wave of HFCV development represent broken waves, whereas HEV development represents a continued wave. Secondly, we applied these findings to the fourth and current wave of EV development to assess if continued technological development is now more likely to occur than during previous broken waves.

Our research design postulates the exclusive study of waves of development, which from a methodological viewpoint is justified. It would be useless to study periods of decreasing interest because the dynamics by which organizations lose interest in a technology are irrespective of the relation between the competitive forces and technological development described in the Theory Section.

In this longitudinal patent study we cover the timeframe 1990-2010, as CVT developments intensified in 1990 (Kemp, 2005) and patent data after 2010 were unreliable due to the eighteen month secrecy period before patent publication (USPTO, 2012). To acquire patent data, we used the European Patent Office's Global Patent Index program (EPO, 2012) because it contains worldwide patent data, which ensured a complete capture of technological development worldwide. More importantly, the program allowed for an increased number of search terms, which was necessary to execute the search queries we developed.

The search queries we used to gather relevant patents can be divided into two categories: 'conventional queries' and 'component queries' (see Figure 2.1). Conventional queries are the types of queries used in the existing literature that specify a particular type of CVT; as such, they specify a vehicular application by adding (vehicle OR automobile OR car) within a two word distance behind the words relating to the type of CVT. Component queries are queries that specify the components of which a CVT is comprised. Figure 2.1 shows that these components can be unique to a specific CVT, or applied in multiple CVTs. More information on the steps taken for search query construction can be found in 'Appendix I – Steps used to construct the search queries'.

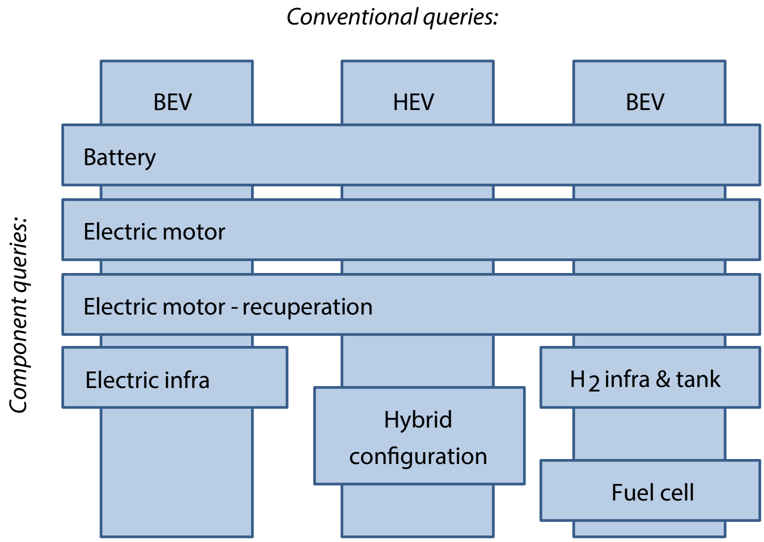


Figure 2.1. Relation between the components (horizontal) and types of CVTs (vertical) included in this study

2.3.3 Operationalization

To study the different propositions, we make use of two populations of organizations depicted in Figure 2.2. Group A in this figure represents the patents developed by a set of large car manufacturers that have played pivotal roles in CVT development (Oltra and Saint Jean, 2009; Frenken et al., 2004). This set comprises the fifteen largest car manufacturers according to the 2010 personal vehicles sales figures from the International Organization of Motor Vehicle Manufacturers (OICA, 2012). They include Toyota, Volkswagen, General Motors, Hyundai, Honda, PSA, Nissan, Ford, Suzuki, Renault, Fiat, BMW, Daimler AG, Mazda and Mitsubishi. Group A was used for propositions 1 and 2, i.e. to research waves of CVT development and rivalry. The analysis of this group makes use of both the conventional and the component level queries because the vehicular application, which was not specified in the component level queries, is guaranteed within this sample of car manufacturers.

Group B represents the patents developed by all other organizations that contributed to CVT development. In our analysis, this group is specifically studied to identify the new entrants specified in proposition 4. To this group we only applied the conventional search queries because, unlike group A, this group does not necessarily work on vehicular product applications. Therefore, when we applied the component queries outside the scope of group A, we got so many irrelevant patents related to products other than cars, that we could not filter them all out. An 'electric motor' for example, is not only used in CVTs, but also in products ranging from torpedoes to elevators.

Finally, to study proposition 3, related to dispersion of technological development, we compared the patents of groups A and B based on conventional search queries.

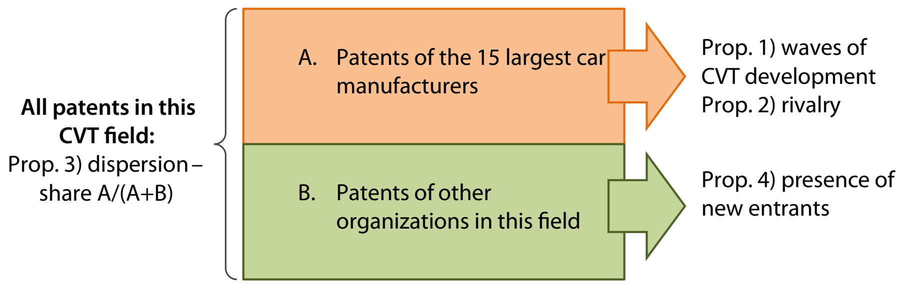


Figure 2.2. How the different types of analyses relate to the set of car manufacturers and other organizations under research (This figure does not represent real data.)

Below we discuss how we operationalized each proposition.

To operationalize the first proposition, we acquired data on the waves of technological development by using the average portfolio share of the sample of car manufacturers. This measure allowed us to control for biases in the absolute numbers of patents over time.

In order to study the second proposition, we measured rivalry by using the conditional entropy of organizational variety, which Frenken et al. (2004) developed to measure rivalry in the field of CVT development. We applied this measure to the sample of rival car manufacturers. The conditional entropy shows the distribution of patent shares of each car manufacturer 'j' in the set of n organizations within a certain type of CVT 'i' (see Eq. 1; for a comprehensive explanation see Frenken et al. (2004)). Entropy and thus rivalry pressure is high when the distribution of patent shares is distributed more equally amongst more rivals (Frenken et al., 2004). The formula reads as follows, for each moment of observation:

$$H(Y|Xi) = -\sum_{j=1}^{n}\left(\frac{Pij}{Pi}\right)\ln\left(\frac{Pij}{Pi}\right) \qquad \text{Eq. 1}$$

With regard to the third proposition, we argue that dispersion and its related competitive pressures are higher when more firms contribute more equally to technological development. We measured dispersion by the share in the total amount of patents that is not accounted for by the sample of car manufacturers. Looking at Figure 2.2, dispersion was determined by the share of patents resulting from group B/(A+B). Because car manufacturers have the highest number of patents in any CVT field, a high share of patents outside the set of car manufacturers indicates that patents are distributed over more firms, thus suggesting high dispersion.

For the fourth proposition we looked at the presence of new entrants, which can be startups or diversifying firms. Startups are firms that did not exist before our timeframe of study (1990). Diversifying firms are firms that started patenting an CVT during the timeframe of study, whereas their initial focus was or still is on a sector other than automotive. We measured the effect of new entrants on CVT development by identifying which of the thirty most important contributing organizations at least doubled their patents during the wave of development, compared to the same time period preceding the respective wave, and identify the new entrants amongst them. We looked at relative increases because the waves of development are also based on relative numbers, i.e. patent shares that increased every successive year. However, because HFCV and HEV development did not have enough patents for analysis in the period preceding the wave and because the period preceding the wave of EV development in the early nineties fell outside the timeframe of analysis (1990-2010), we only focused on the current wave of EV development.

2.4 Results and analysis

This results section is structured in line with the sequence of propositions. Accordingly, we start by identifying waves of development in Section 4.1. Subsequently, we discuss rivalry in 4.2; dispersion in 4.3 and the presence of new entrants in 4.4. Finally, in Section 4.5 we combine the data on these forces and describe how together they influence the continuation of waves of CVT development.

2.4.1 Proposition 1: Verifying waves of CVT development

In Figure 2.3 the fifteen largest car manufacturers' annual portfolio shares per type of CVT for the period 1990-2010 are displayed. Figure 2.3 presents the waves of CVT development as solid lines, whereas the periods without high expectations are indicated by dotted lines. The first broken wave of development is that of EV development during the period 1990-1994. Subsequently, there is a wave of continued HEV development from 1996 onwards with a second boost in development from 2006 until 2008, well after commercial success (Dijk and Yarime, 2010), after which stagnation takes place. At the same time, a broken wave of HFCV development takes place from 1998 to 2007. Finally, the figure verifies that the current wave of EV development is supported by increased patent activities and therefore constitutes not only an increase in the number of prototypes and production models as found by (Sierzchula et al., 2012a), but also increased R&D. This wave of EV development took off around 2006[1]. The data in Figure 2.3 coincide well with the waves of development identified in previous studies[2]. These corresponding findings support "proposition 1: Waves of CVT development identified in previous studies are characterized by technological progress and therefore reflected by peaks in patent data".

1 The fact that the share of EV patents is smaller than the share of HFCV patents in 2010 does not mean that HFCV is still getting more attention; this difference can also be explained by the differences in tendencies to patent over technology fields (Van den Hoed, 2005).

2 However, the wave of EV development that Frenken et al. (2004) identify in the early nineties seems to have a time lag compared to ours, as the wave they identify starts in 1994, while we observe an increase in EV development already in 1990. Their time lag might be explained by their use of a patent's 'issue date' compared with our 'date of application', as the latter minimizes the time elapsed after invention.

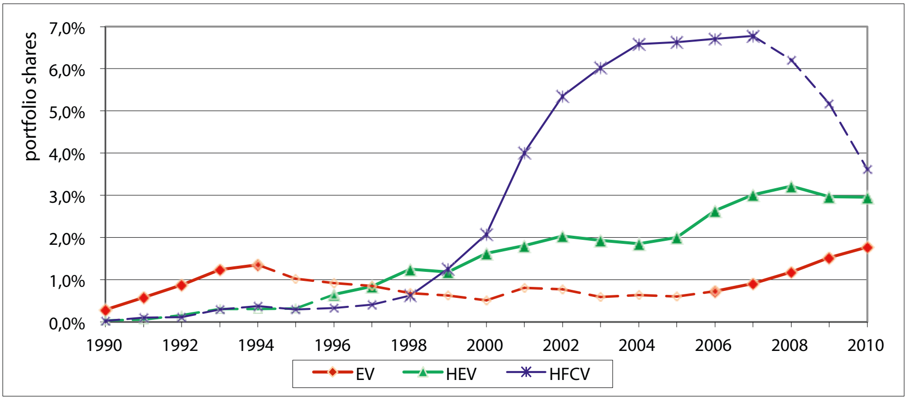


Figure 2.3. Trends in the fifteen car manufacturers' annual portfolio share per type of CVT over the period 1990-2010.

2.4.2 Proposition 2: Rivalry within waves of CVT development

Figure 2.4 displays the trends in organizational variety during the waves of CVT development identified in the previous section between the fifteen largest car manufacturers in the fields of EV, HEV and HFCV, by the use of a conditional entropy measure[3]. This figure shows that during the continued wave of HEV development, rivalry increases over time and that during the broken wave of HFCV development, rivalry decreases over time. This suggests a positive correlation between rivalry and continuation of technological development. However, the broken wave of EV development in the early nineties also displays an increasing trend in rivalry; in this case there is a negative correlation. This negative correlation contradicts the expected positive correlation, but as the theory section suggested, can be explained by a coinciding decrease in dispersion, which will be described in the next section[4]. Nevertheless, it is impossible to confirm "proposition 2: Increasing rivalry correlates with continued waves of CVT development" on the basis of these data. Section 4.5 further analyses how the coincidence of rivalry and dispersion affects continuation of CVT development.

3 1998 is missing in the HFCV trend because too few data was available to appropriately calculate the dispersion measure for that year.

4 Further to the negative effect of decreasing dispersion, several studies (Pilkington and Dyerson, 2006; Collantes and Sperling, 2008; Hoogma, 2000) stress that the relaxation of the Zero Emission Vehicle regulation, mandated by the Californian Air Resources Board, contributed to the discontinuation of this wave of EV development.

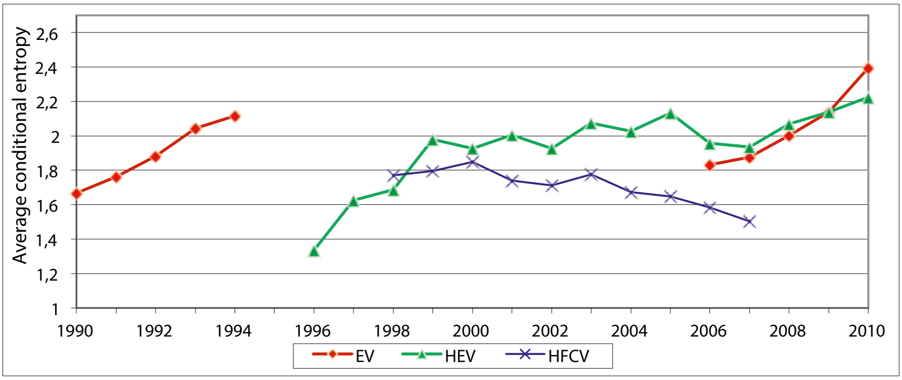


Figure 2.4. Rivalry, measured by conditional entropy of organizational variety within the fields of EV, HEV and HFCV over the period 1990-2010.

2.4.3 Proposition 3: Dispersion within waves of CVT development

Figure 2.5 displays the trends in dispersion, measured by the share of patents that fall outside the scope of the set of large car manufacturers, during waves of CVT development. The higher the share that falls outside this set, the more dispersed technological development is. On the one hand, Figure 2.5 shows trends of decreasing dispersion for the broken waves of EV (in the early 1990s) and HFCV development. On the other hand, HEV development shows an initial decline in dispersion, which is explained by our data showing that Toyota and Honda dominate HEV development, especially in the period 1996-2004. Subsequently, dispersion increases in the period 2004-2010 as other firms enter the field. This suggests that not only rival car manufacturers were triggered to enter the field of HEV by its commercial success (Dijk and Yarime, 2010; Chanaron and Teske, 2007), but also organizations outside the set of car manufacturers. Overall, the continuation of the wave of HEV development coincides with increasing dispersion. These findings support "proposition 3: Increasing technological dispersion is positively related to continued waves of CVT development". On a different note, it is surprising to see that over the 21 year period, the average dispersion in the field of EV (81.0%) is structurally significantly higher than that of HEV (39.2%) and HFCV (19.8%).

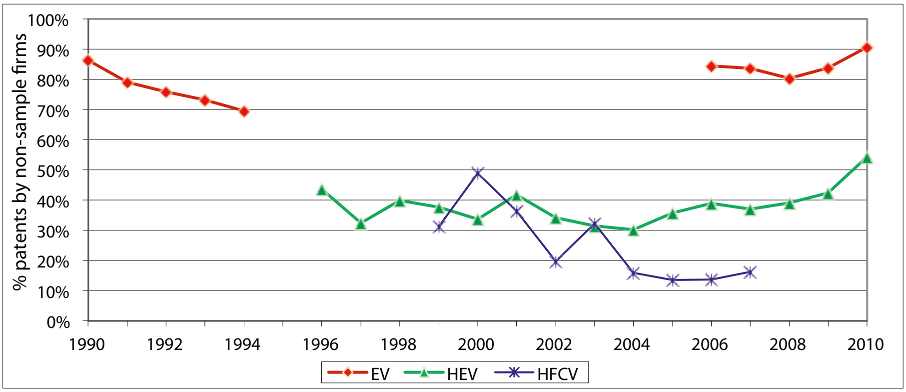


Figure 2.5. Patent share of organizations outside the set of fifteen largest car manufacturers in the total number of patents for different types of CVTs during waves of CVT development over the period 1990-2010

Furthermore, the current wave of EV development is characterized by an increase in dispersion, which means that although the patent portfolio share of the fifteen largest car manufacturers increases strongly (as signified by the wave of development), the share of these firms in the total number of EV patents declines. This suggests that although car manufacturers are increasingly developing EV technology, they cannot keep up with the general rate of development in the field of EV. This suggests that their competitive position in EV development relative to other organizations in this field is declining, or that they are focusing their activities. The fact that increasing numbers of firms are contributing to the wave of EV development suggests that continuation of this wave is likely.

2.4.4 Proposition 4: The role of new entrants

Table 2.1 presents the firms in the top thirty most important patent owners over the wave of EV development (2007-2010) that at least doubled their number of patents compared to the four-year period preceding this wave (2003-2006). Table 2.1 shows that only two incumbent firms account for a large part of the current wave of EV development, compared with 5 startup firms and 4 diversifying firms. These new startup firms are active in different loci of the EV-supply chain, e.g. Tesla Motors and Leo Motors (car manufacturer/developer), V-ENS (EV-manufacturing consultant), Better Place (infrastructure provider) and V2Green (vehicle-grid integration). In conclusion, new entrants, both startups and diversifying organizations, are playing an important role in the current wave of development that involves the competence-destroying EV technology. Although we could not study "proposition 4: The presence of new entrants is positively related to continued waves of competence destroying CVT development", over the different fields of CVT, this proposition suggests that the presence of various new entrants sustains the current wave of EV development.

Table 2.1. Firms accounting for the largest increase in EV patents between the periods 2003-2006 and 2007-2010

Organization	Patents 2003-2006	Patents 2007-2010	Contributing rank in 2010	Type of organization
Korea Adv. Inst. of Science	0	182	1	diversifying
Chery Automobile	5	114	5	incumbent
Tesla Motors	0	90	7	startup
Siemens	10	80	9	diversifying
RWE	0	47	13	diversifying
General Electric	2	46	14	diversifying
Better Place	0	41	15	startup
V2Green	0	35	18	startup
V ENS	0	33	20	startup
Bosch	6	36	17	incumbent
Leo Motors	0	28	22	startup

2.4.5 Overview of the results

In our theory section we suggested that it is not necessarily the individual competitive forces that trigger continued waves of CVT development but the combination of these forces. In this section we focus on how rivalry and dispersion (as the presence of new entrants could not be measured for all waves of CVT development) together affect the continuation of waves of CVT development. Table 2.2 provides an overview of the way these concepts coincide with the identified waves of CVT development. Table 2.2 shows that, when rivalry and dispersion decrease, i.e. in the case of HFCV, this coincides with a broken wave of development. Moreover, when rivalry and dispersion increase, i.e. in the case of HEV, this coincides with a continued wave of development. These findings seem to suggest that both rivalry and dispersion should increase for a wave of CVT development to become continued. However, the broken wave of EV development shows that when rivalry increases and dispersion decreases, this does not relate to a continued wave of development. This suggests that the negative effect of dispersion might be more significant than the positive effect of rivalry in relation to continued development.

Table 2.2. Overview of the results

	Wave of CVT development			
Indicator	EV '90s	HFCV	HEV	EV currently
Rivalry	(+) increase	(-) decrease	(+) increase	(+) increase
Dispersion	(-) decrease	(-) decrease	(+) increase	(+) increase
Presence of new entrants	(..) n.a.	(..) n.a.	(..) n.a.	(+) yes
Sustained wave?	(-) no	(-) no	(+) yes	(?) uncertain

Looking at the current wave of EV development, we find that not only rivalry and dispersion support continued development, but, as suggested by proposition 4, also the presence of new entrants. This suggests that the current wave of EV development is likely to become continued due to the different competitive pressures created by the numerous and different types of actors that are supporting this wave of technological development.

2.5 Conclusions and discussion

This research tackled the question "How did the forces of rivalry, dispersion and the presence of new entrants affect the duration of earlier waves of CVT development and how do these competitive forces affect the chances of continuation of the current wave of EV development?" With respect to the first part of this question, our empirical study appears only to confirm the individual positive relationship between dispersion and the continuation of earlier waves of CVT development. Moreover, our case studies suggest that the combination of rivalry and dispersion is positively related to the continuation of waves of CVT development. The data did not allow us to test this relationship for the presence of new entrants, which theory proposed to positively influence continued CVT development. Because our findings are drawn from only three case studies and the effect of the presence of new entrants could not be established, it is necessary to improve the validity of the effect the three competitive forces have on continued technological development. Therefore, we recommend future research to further look into this relation. With respect to the second part of our question, we find that rivalry and dispersion each supports future continuation of the current wave of EV development, and that new entrants play an important role in current EV development. In other words, current EV developments are driven by an increasing number of organizations, including new entrants. Through competitive pressures these organizations continuously induce each other to invest more in the technological development of the EV. We expect these dynamics to sustain the current wave of EV development.

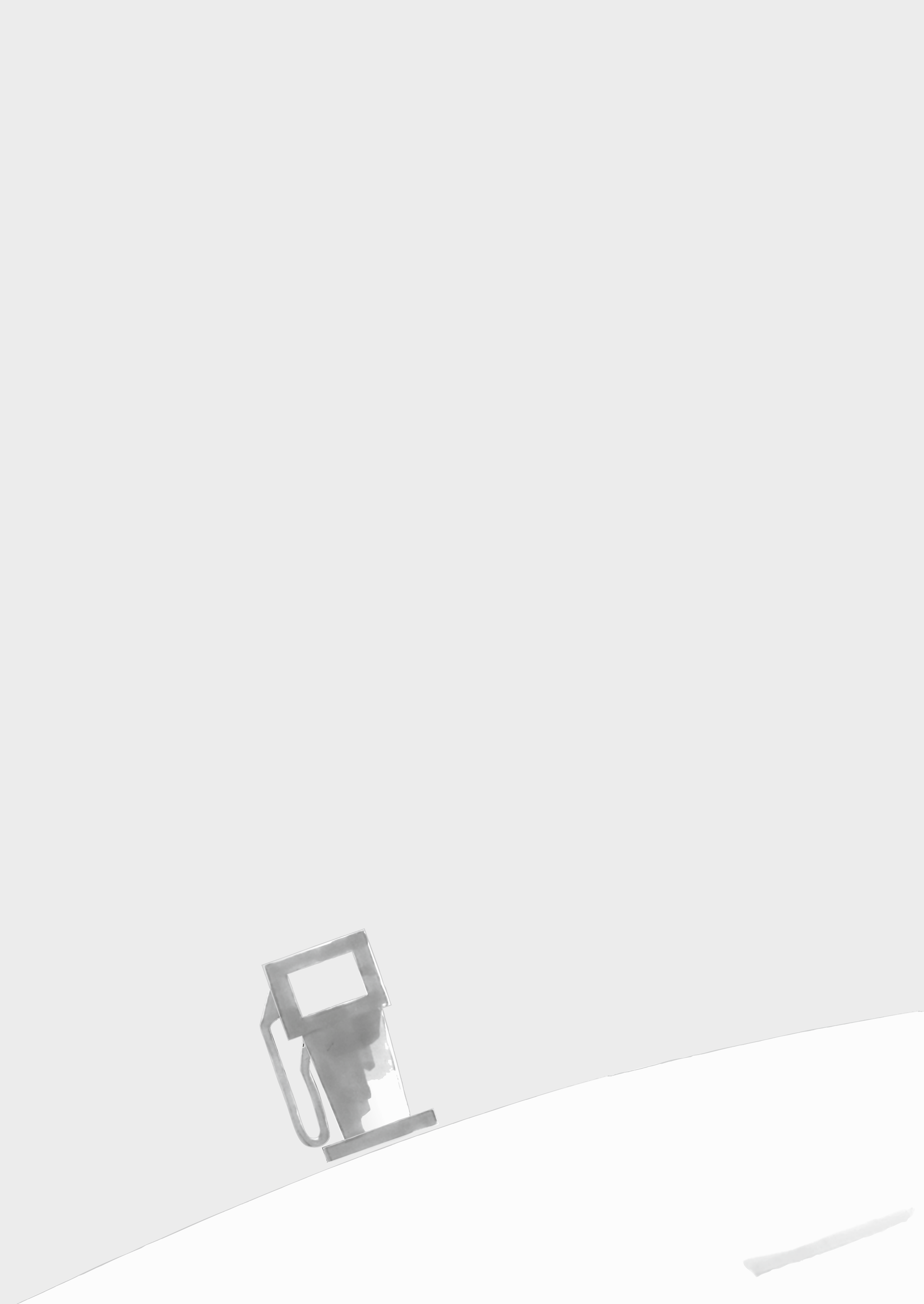
This study has taken a different approach to assess the chances of success of a new technology by focusing on how competitive forces affect the supply side of CVTs. In taking this specific focus, our study did not take into account some aspects that influence the success of CVTs. For example, the role of institutional developments and emergence of markets were, although important, not incorporated in this study. Another important aspect that should be taken into account is the interaction of the established ICEV that still dominates the automotive sector with CVTs (Dijk and Yarime, 2010). Sailing-ship effects have been identified for the ICEV (Oltra and Saint Jean, 2009), which can hamper CVT's chances of success. Because this study has a specific focus on competitive forces and the supply side, it is complementary to, and accordingly should be consulted within the context of CVT assessments that have a different focus.

To recap the contributions of this chapter stated in the introduction, we firstly provide a more contemporary study on the forecasting of continued development of the EV that is based on improved search queries as well as an improved set of competition-based indicators that incorporate all relevant actors. Secondly, our analysis has shed new light on the dynamics of technological development during the life cycle's era of ferment. Thirdly and maybe most importantly, our newly introduced set of competition-based factors is useful for technological forecasting in general. Little attention has been paid so far to the role of technological competition in technological forecasting. Although the competitive force rivalry has been studied in a similar context by Frenken et al. (2004), we widened the scope on competitive forces by also including dispersion and the presence of new entrants. Our analysis shows that adding dispersion is important to understand why some waves of technological development ended. We recommend further research to validate the effect of these competitive forces on the continuation of technological development; especially how this effect changes when the technology under focus matures, as our study was delineated to emerging technologies in eras of ferment.

Based on our study, we make some recommendations for further research. First, we found major structural differences between the dispersion of EVs and HEVs and HFCVs. We recommend further research to look into why large car manufacturers so extensively dominate HFCV development, whereas their role in EV development is relatively small.

Additionally, we identified a relation between high dispersion of EV development and the high number of startups in this field. This relation suggests that dispersion has an entry barrier lowering effect. The fact that the EV relies on more mature technological fields and the fact that EV development is dispersed amongst a larger number of organizations, suggests that EV knowledge is more competitively available. Illustrative is the provision of batteries by a wide range of suppliers that are diversifying their market range (Lowe et al., 2010). More competitively available knowledge lowers entry barriers, especially for startups that incorporate different knowledge/components to create a product or service, e.g. car manufacturers. This explains the presence of startups, especially startups like Tesla and Leo Motors, in the field of EV. Through these same dynamics, the lack of dispersion and the absence of related mature technological fields might also explain why there are no startup car manufacturers involved in the development of the competence-destroying technology of HFCV (Van den Hoed, 2004). A complementary explanation for the lack of new entrants in this field is the lack of infrastructure and demand for the expensive HFCVs. Because of the uncertainty on this topic, we recommend future research to further analyze the relation between dispersion and the entrance of startups.

Finally, in this study we only focused on the development of CVT knowledge, but the diffusion of CVT knowledge through networks of inter-firm alliances is also found to play an important role in the transition towards CVTs (Sierzchula et al., 2012c). Because firms use both internally developed knowledge and externally acquired knowledge to create products as complex as CVTs (Sierzchula et al., 2012c), we recommend future research to investigate the roles of both internal development and external acquisition of CVT knowledge. This will provide a more comprehensive view on the possible transition towards CVTs.



3 Business strategies of incumbents in the market for electric vehicles: Opportunities and incentives for sustainable innovation

Abstract

This chapter focuses on the relation between large car manufacturers' incentive and opportunity to innovate and their Electric Vehicle (EV) business strategies. We analyze how environmental regulation and the firm's incentive (measured by net income) and opportunity to innovate (measured by EV asset position, determined from a combination of patent, partnership and prototype data) affect EV sales over the period 1990-2011. During the EV's R&D period in the 1990s, large car manufacturers that were regulated by the full Zero Emission Vehicle mandate developed a significantly stronger EV asset position, but did not sell significantly more EVs than their rivals. During the EV's commercialization period (2007-2011), large car manufacturers with both a strong incentive and a strong opportunity to innovate sold significantly more EVs. Based on these results, the chapter offers a typology of business strategies, several managerial implications and recommendations for policy makers to stimulate sustainable development.

This chapter is based on Wesseling JH, Niesten EMMI, Faber J, Hekkert MP. 2014. Business strategies of incumbents in the market for electric vehicles: Opportunities and incentives for sustainable innovation. Business Strategy and the Environment. http://onlinelibrary.wiley.com.proxy.library.uu.nl/doi/10.1002/bse.1834/full

3.1 Introduction

Full-electric vehicles (EVs) are an important technological solution to our unsustainable mobility system. The EV constitutes a radical innovation that completely differs from the established internal combustion engine vehicle (ICEV) (Bakker et al., 2012a). Radical innovations build on a completely new technology (Tushman and Anderson, 1986) and tend to be competence-destroying for incumbents, because these innovations require radically different skills when compared to the established technology (Henderson and Clark, 1990). The competence-destroying nature of radical innovations has led several scholars to conclude that incumbents are inhibited from pursuing radical innovations (e.g. Ahuja and Lampert, 2001; Christensen, 1997; Henderson, 1993; Nelson and Winter, 1982; Schaltegger and Wagner, 2011), while others have argued that some incumbents do have an opportunity to radically innovate (e.g. Chandy and Tellis, 2000). In this study we aim to determine why some incumbent car manufacturers do radically innovate in the field of EVs, and others do not. The literature on incumbents and innovation has analyzed incumbents as a homogeneous group. We contribute to this literature by studying the differences between incumbents in their decision to pursue radical and sustainable innovations.

For a large car manufacturer to exploit an innovation as the EV, it needs both an incentive and an opportunity to innovate (Swann, 2009). The incentive to innovate refers to the incentive of firms to enhance their competitiveness and increase their market share by introducing innovations (Swann, 2009: 218). The opportunity to innovate refers to the investments a firm can make to support innovation (Swann, 2009). Firms reveal their opportunity to innovate by the amount of assets they have built up in a particular technology (Lieberman and Montgomery, 1998; Silverman, 1999). The literature suggests that incumbents may have an opportunity to innovate (Chandy and Tellis, 2000), i.e. the assets necessary to exploit an innovation, but not the incentive, because they do not want to cannibalize on their own profitable products that are built on the existing technology (Ali, 1994; Chandy and Tellis, 1998; Reinganum, 1983).

In recent history, the EV experienced several periods of increased interest by large car manufacturers, triggered by factors such as regulation, competition and technological development (Mom, 2004; Kemp, 2005; Wesseling et al., 2014a). In the 1990s, regulations were implemented that triggered large car manufacturers to develop more sustainable vehicles. The Californian Air Resources Board's (CARB) introduction of the Zero Emission Vehicle (ZEV) mandate in 1990 is an important piece of legislation in this respect. Chapter 2 shows that since 2007 several large car manufacturers have pursued the commercialization of the EV, driven by new technological developments. In this study we aim to gain more insight in what drives incumbent car manufacturers to radically innovate in the EV market. We pose the following research question: 'How did the incentive and opportunity to innovate affect large car manufacturers' decision to mass market EVs over the period 1990-2011?'.

We measure the incentive and opportunity to innovate by using a comprehensive set of data on, respectively, the profitability of car manufacturers in the ICEV regime, and on patents, prototypes and partnerships as proxies for the asset position of incumbent car manufacturers. We use this data in combination with data on EV sales, to analyze the impact of incentive and opportunity to innovate on incumbents' decision to mass market EVs. We focus our study on the timeframe 1990-2011 to compare the incentive and opportunity to innovate over different periods of EV interest. On the basis of our quantitative analyses and using this timeframe, we identify three different types of business strategies of the large car manufacturers, i.e. the first mover, quick follower and laggard strategies. In our typology of business strategies, we show how these strategies are determined by the firms' incentive and opportunity to innovate.

The chapter is structured as follows. In the following section, we formulate hypotheses on car manufacturers' incentive and opportunity to innovate, and discuss the literature on business strategies. In the section on methods, we discuss the operationalization of our concepts and the data collection and analysis. The section on results presents our findings resulting from a series of nonparametric tests to study our hypotheses, and a more qualitative analysis of large car manufacturers' business strategies. The two final sections offer a conclusion and present some limitations and suggestions for future research.

3.2 Theoretical framework

In this section, we argue that a firm requires both an incentive and an opportunity to radically innovate, and stress that the incentive and opportunity to innovate determine the business strategy of the firm, be it a first mover, quick follower or laggard strategy (Freeman and Soete, 1997; Lieberman and Montgomery, 1998). We also discuss how car manufacturers' business strategies can be affected differently by the market and regulatory developments that took place throughout the timeframe of this study.

3.2.1 The incentive and opportunity to radically innovate

The incentive to innovate refers to the incentive of firms to enhance their competitiveness and market share by introducing innovations (Swann, 2009: 218). Profitable firms with a strong competitive position in the established technology have less incentive to radically innovate (Chandy and Tellis, 2000), as radical and competence-destroying innovations endanger their competitive positions in the established technology (Tushman and Anderson, 1986). However, for firms with inferior competitive positions, radical innovation may be a means to escape their income-restraining situation in the existing market (Swann, 2009; Mensch, 1979; Barley, 1986). We expect that firms with a stronger incentive to innovate (i.e. less profitable firms), will introduce more EVs into the market.

According to Swann (2009), an opportunity to innovate depends on the financial possibilities of a firm to invest in innovation, and can be measured by a firm's capital available for investments in R&D. However, before firms are able to introduce an innovation into the market, they need to invest capital in assets that facilitate the development of an innovative technology. In line with the resource-based view of the firm, we therefore consider the assets of a firm as a more direct measure of the firm's opportunity to innovate (e.g. Silverman, 1999). A firm's opportunity to innovate is determined by its unique and difficult to imitate resources, i.e. its assets that are necessary for the exploitation of the radical innovation (Teece et al., 1997). The aggregate of a firm's assets is referred to as its asset position, comprising technological, infrastructural, complementary and reputational assets. Technological assets entail protected knowledge necessary for the development and application of an innovation (Pavitt, 1998), e.g. EV specific knowledge. Infrastructural assets refer to the technologies necessary for infrastructure-dependent innovations to operate profitably (Teece, 2006), e.g. an EV's charging infrastructure (Egbue and Long, 2012). Complementary assets are crucial to profit from innovations and include, for example, distribution channels, marketing and manufacturing facilities (Pinkse and Kolk 2010; Rothaermel, 2001). Finally, reputational assets result from the company's alignment with existing norms and values, which forms customers' perception of the company, especially their brand experience (Teece et al., 1997). The strategic importance of these four assets has been acknowledged in the field of EVs for technological assets (Wesseling et al., 2014a; Van Den Hoed, 2005), infrastructural assets (Egbue and Long, 2012; Pohl and Yarime, 2012), complementary assets (Dyerson and Pilkington, 2005) and reputational assets (Bakker, 2010). We expect that firms with a stronger opportunity to innovate, (i.e. firms with a greater EV-related asset position), will introduce more EVs into the market.

3.2.2 Business strategies

The business strategy of a firm dictates how the firm intends to exploit a radical innovation; a firm may employ different business strategies for different innovations (Freeman and Soete, 1997; Lieberman and Montgomery, 1998; Teece et al., 1997). In the literature on business strategies, a distinction is made between three types of business strategies: first movers, quick followers and laggards (Robinson and Chiang, 2002). First movers intend to become mass-market pioneers and subsequently stay ahead of competitors through technological lead-time (Freeman and Soete, 1997; Golder and Tellis, 1993). Firms with a quick follower strategy leave the decision of exploiting a radical innovation open, until a first mover goes to the market. Quick followers attempt to avoid the costly mistakes made by first movers and quickly follow them onto the market (Freeman and Soete, 1997; Lieberman and Montgomery, 1998). Laggards are less engaged in innovative activities and attempt to acquire rents from reducing overall costs by minimizing R&D. They enter the market last (Freeman and Soete, 1997; Jovanovic and MacDonald, 1994).

Relating these three business strategies to the concepts of incentive and opportunity to innovate and to the case of EVs, we expect firms with a strong incentive and a strong opportunity to radically innovate to adopt a first mover EV strategy as these firms are most willing and able to bear the costs and risks of pioneering the radical innovation and its necessary infrastructure. Firms with some incentive and opportunity to innovate are likely to employ a quick follower strategy, as they may not be willing or able to pioneer the innovation, but do not want to fall behind on their more innovative rivals. Firms with little incentive and/or little opportunity to innovate are expected to employ a laggard strategy, as they are not willing and/or not able to introduce the radical innovation into the market.

3.2.3 External impacts on strategies

The incentives and opportunities of firms to innovate, and their business strategies, may be influenced by factors external to the firm. Firms operate in a system of regulatory, market and technological components that changes over time and influences the business strategies of firms (Hekkert et al., 2007). Especially in the field of EVs, significant regulatory, market and technological developments have taken place over the period 1990-2011 (Magnusson and Berggren, 2011; Wells and Nieuwenhuis, 2012; Wesseling et al., 2014a). During the 1990s, EV developments were especially stimulated by regulatory developments, as substantial consumer demand for EVs was lacking (Collantes and Sperling, 2008) and technological hurdles needed to be overcome (Dyerson and Pilkington, 2005). The most influential policy was a technology-forcing, 'command and control' (Prakash and Kollman, 2004) regulation called the Zero Emission Vehicle (ZEV) mandate, introduced by the Californian Air Resources Board (CARB) in 1990 (Collantes and Sperling, 2008; Hoogma, 2000; Kemp, 2005). The regulation mandated a stepwise increase in sales of EVs over the period 1998-2003 (CARB, 1990). This mandate fully applied to car manufacturers that sold more than 35,000 vehicles in California per year and included Chrysler, Ford, General Motors, Honda, Mazda, Nissan, and Toyota (Collantes and Sperling, 2008). However, in 1996 oil companies and car manufacturers lobbied against the continuation of this mandate, resulting in relaxation and extension of the mandated targets (Hoogma, 2000). Because of this decrease in regulatory pressure, car manufacturers lost interest in EVs and started to refocus on HEVs and HFCVs (Dijk and Yarime, 2010; Wesseling et al., 2014a). Technological and market uncertainty prevented car manufacturers from exploiting EVs more extensively during the 1990s (Dyerson and Pilkington, 2005). Because EV developments during the 1990s were primarily triggered by the ZEV mandate, we formulate the following hypothesis:

Hypothesis 1: Large car manufacturers that fell under the full ZEV mandate will have a) developed a stronger opportunity to innovate and b) will have marketed more EVs during the 1990s than large car manufacturers that did not fall under this mandate.

Chapter 2 shows that in the late 2000s, car manufacturers regained interest in the EV. During this period car manufacturers were not triggered by stringent technology-push regulation. Instead, car manufacturers saw market opportunities emerge for the EV (Magnusson and Berggren, 2011). These opportunities emerged because technological hurdles like battery costs (Gärling and Thøgersen, 2001) were partly overcome due to developments in other sectors (Magnusson and Berggren, 2011). Furthermore, tax rebates for consumers supported the adoption of EVs (Magnusson and Berggren, 2011; Sierzchula et al., 2012b). The fact that EVs became an emerging market opportunity in the late 2000s implies that large car manufacturers may now attempt to exploit the commercialization of EVs, and especially car manufacturers with an incentive and opportunity to innovate. We formulate the second hypothesis as follows:

Hypothesis 2: Large car manufacturers that have a stronger incentive and opportunity to innovate will have marketed more EVs than their competitors during the early stage of EV commercialization.

3.3 Methods

In this section, we discuss the research design, operationalization, data collection and analysis.

3.3.1 Research design and operationalization

Technological development of low emission vehicles has been studied using indicators like patent applications, prototypes, production models and partnerships (Bakker, 2010; Bakker et al., 2012b; Frenken et al., 2004; Sierzchula et al., 2012a; Wesseling et al., 2014a). So far, however, no research has yet attempted to combine these different indicators. In this chapter, we use a combination of indicators, presented in Table 3.1, which enabled us to study more comprehensively the differences in incentive and opportunity to innovate and in the EV business strategies of large car manufacturers.

Our analysis focuses on the period 1990-2011, because 1990 marks the start of a period of renewed interest in the EV, caused by the CARB's ZEV mandate (Hoogma, 2000). We define large car manufacturers as car manufacturers producing more than a million personal vehicles in the year 2011. In 2010 and 2011, the same fifteen car manufacturers fit this definition (OICA, 2011; OICA, 2012). We study each of these firms, meaning that our research sample matches our research population. These firms accounted for 84.4% of all personal vehicle sales in 2011, and include Toyota, Volkswagen, General Motors, Hyundai, Honda, PSA, Nissan, Ford, Suzuki, Renault, Fiat, BMW, Daimler AG, Mazda and Mitsubishi (OICA, 2012).

Table 3.1 displays how each of the concepts, discussed in the previous section, is operationalized into their respective indicators and what sources are employed to retrieve data on these indicators. First, whether a firm was subject to technology-push policy was measured by whether it fell under the full ZEV mandate. Six of the fifteen car manufacturers fell under this restriction. Second, the incentive to innovate, approached by a firm's profitability in the ICEV regime was measured by the firm's net income. ICEVs account for more than 95% of vehicle sales (Pohl and Yarime, 2012) and net income of a firm is therefore considered a good indicator for its profitability in the ICEV regime.

Third, the opportunity to innovate, or asset position, is comprised of several types of assets, each with its specific indicators. Technological assets encompass knowledge and components related to the EV itself. They may be developed internally, measured by patents, or externally, measured by partnerships. Infrastructural assets were measured by patent applications and partnerships aimed not at the EV itself, but at its charging infrastructure and compatibility with this infrastructure. Complementary assets were measured by partnerships geared towards acquiring assets that are necessary to exploit an innovation, like production facilities and distribution channels. Reputational assets are measured by prototypes, which are models presented at auto-shows that, at the time of presentation, were not (yet) in production. Prototypes of low emission vehicles have an important signaling role; they boost company reputation and influence external actors, like policymakers and consumers (Bakker et al., 2012b; Autoweek, 2013; General Motors, 2012; Volkswagen, 2012). Creating an innovative and sustainable company image was key to promoting prototypes (Ibid.). Fourth, the firm's EV business strategy was measured by its EV sales volume. Complementary information, including the moment the vehicle was first commercially available; the number of models introduced into the market; and whether the EVs sold are purpose-built EVs or based on an ICEV model, will be used to classify the exact EV business strategies of large car manufacturers.

Table 3.1, Concepts, indicators and data sources.

Concepts:		Indicators:	Data sources:
Subject to technology-push policy		Falling under the CARB's full ZEV mandate	CARB (1990)
Incentive to innovate / profitability in the ICEV regime		Net income in dollars	Datastream
Opportunity to innovate / Asset position	Technological assets	Patent applications and partnerships oriented at developing or exchanging EV knowledge or EV components	IPO patent database and media statements; company websites
	Infrastructural assets	Patent applications and partnerships oriented at developing or exchanging EV-infrastructure knowledge or EV-infrastructure components	IPO patent database and media statements; company websites
	Complementary assets	Partnerships geared towards acquiring production facilities and distribution channels	Media statements; company websites
	Reputational assets	Prototypes, i.e. models presented at auto shows that are not (yet) in production	Annual reports, websites, documents
EV market strategy		EV sales volume	Annual reports, websites, documents
		Complementary information, including timing to market; number of models introduced on the market; purpose-built EV or not	Annual reports, websites, documents, interviews

3.3.2 Data collection

Data on car manufacturers' annual net income in dollars were obtained from the global financial database Datastream of Thomson Reuters.

Worldwide patent data were collected using the International Patent Office's (IPO) Global Patent Index program. We used patent applications instead of patent grants, because a significant amount of patent documents do not provide information on patent grants at the time of indexing (European Patent Office, 2013). A publication level filter excluded patent applications that were withdrawn during the period of secrecy. To select patent applications related to technological and infrastructural assets, we used a search query based on EVs and EV infrastructure respectively. Due to the 18-month period of secrecy and processing time of patent applications, the database does not include all patent applications of recent years. We controlled for the decreasing trend in patent applications by dividing the number of EV and infrastructure related patent applications of each large car manufacturer in every year by the total amount of patent applications of the fifteen car manufacturers in the same year. Our patent study resulted in 7611 patent applications.

Partnership data were collected from 'all major world publications' in the LexisNexis media database. Such media-oriented data collection approaches have been applied to construct various professional databases (Schilling, 2009) and have yielded reliable results for inter-firm analyses (Hagedoorn, 2002; Rice and Galvin, 2006). We applied a search query that contains any combination of words that include 1) any term synonymous with or comparable to 'partnership'; and 'electric vehicle'; and 2) to further narrow down the results and improve relevance the articles should include the term 'battery or batteries'[5]. This query provided 6151 articles that were published in the period 1990-2011. Each article was scanned for relevant partnerships. Company websites and annual reports were consulted for additional information. We included only reports of partnerships that had already been formed, announcements of future formations were omitted, and double counts of partnerships were excluded. This resulted in 171 relevant partnerships.

Based on the work of Sierzchula et al. (2012b), prototype data were collected using different sources, including government reports, annual reports, websites, auto-shows, newspaper articles, company press releases or personal contacts with the manufacturer. Combining these sources allows for a broader coverage of prototype models and the triangulation that is needed to pinpoint the exact date of each prototype's release. A total of 126 prototypes were included.

EV sales data were based on websites, documents and car companies' annual reports. These sales data were collected in 2012 and attributed to each production model's year of market introduction. Sales data of a total of 37 commercialized EV production models were included in our database.

To get more information on car manufacturers' business strategies, besides consulting websites, documents and annual reports, we conducted complementary interviews with managers of car manufacturers.

5 These search terms refer to the most important component of the EV, and often form the basis in patent analyses to acquire EV related patents (Oltra and Saint Jean, 2009).

3.3.3 Data analysis

To test our hypotheses, we took several interrelated steps. First, we defined periods in the car manufacturers' R&D and commercialization trends, to highlight significant changes in EV strategies over time and to focus our analysis on periods of interest. We measured R&D trends by our indicators for technological assets; trends in commercialization were measured by EV sales per production model year.

Second, we conducted a Principal Component Analysis (PCA) to aggregate the data on the different types of assets into one component representing asset position. Use of PCA for this purpose was supported as all indicators that made up the asset position correlated well with each other ($p<0.05$) and the Scree-plot's inflexion point suggested the use of one component. The Kaiser-Meyer-Olkin measure showed a score of 0.711, which according to Hutcheson and Sofroniou (1999) yields a reliable factor. Bartlett's test of sphericity confirmed that correlations between the indicators were sufficiently large for PCA ($p<0.001$). The component explained 61.5% of the indicators' total variance.

In the third step of the analysis we tested our hypotheses using nonparametric Mann-Whitney tests, because our data are not normally distributed and the Mann-Whitney test is, for our purposes, the most powerful nonparametric test for smaller samples (Mann and Whitney, 1947). Mann-Whitney tests have yielded reliable results for samples smaller than 15 (e.g. Bocken et al. 2012). Levene's tests show that for each between groups comparison the requirement of homogeneity was met, as the variances between groups were not significantly different. Because we tested predefined hypotheses, the 1-tailed exact significance values could be used to determine the significance levels of the between group differences.

To test Hypothesis 1, we created a group of firms that fell under the full ZEV restriction and a group of firms that did not fall under the restriction; we compared them in terms of asset position and EV sales. To test Hypothesis 2, whether firms with a strong incentive and opportunity to innovate will have commercialized more EVs during the period of commercialization, we first created two groups of firms. One group of firms was created with a below average net income and an above average asset position (i.e. strong incentive and opportunity to innovate). The EV sales of this group are compared to those of a group that comprises the remainder of the population of large car manufacturers.

Fourth, to analyze how different car manufacturers' business strategies relate to their incentive and opportunity to innovate, we plot each firm's profitability in the ICEV regime against its asset position and its EV sales, to identify clusters of strategies. To gain more in-depth insight in business strategies, we link our quantitative data to more qualitative data on individual firms' EV strategies.

3.4 Results

This section presents the periods of EV development in terms of trends in R&D and commercialization, the results of the Mann-Whitney tests that were used to test our hypotheses, and it categorizes the business strategies of large car manufacturers.

3.4.1 Periods of R&D and commercialization

Figure 3.1 displays the trends in the aggregated R&D and commercialization endeavors of the population of large car manufacturers over the period 1990-2011. Displayed on the left-hand y-axis, large car manufacturers' R&D trends, measured by their technological assets, are presented in broken, blue lines. The dark blue line represents technological assets measured by large car manufacturers' total number of EV related patent applications, divided by 25 to fit the graph. The light blue line represents technological assets measured by large car manufacturers' EV related partnerships. The commercialization trend is presented in green with EV sales volume per model year[6], depicted on the right hand y-axis.

Based on these trends we can identify three distinctive periods: an R&D period, a period of inactivity and a commercialization period. The first period started in 1990 and is characterized by a strong initial increase in R&D (blue lines),

6 The model year refers to the year an EV production model was introduced into the market.

followed by the introduction of some production models that were restrictively sold on the market (green line) (Whiteman et al., 2011). Accumulated EV sales reached approximately 10.6 thousand vehicles in this period. Because of its strong focus on R&D, we label this period the R&D period.

Over the timeframe 2000-2006, relatively little EV related activities took place compared to the previous period. Car manufacturers continued only to file a low and steady number of patent applications (dark blue line). Because of the low R&D activity and the lack of commercial activities during this period, we label it the period of inactivity.

As of 2007, a third period can be distinguished that started with a strong increase in EV related technological assets (blue lines). This increase in R&D is followed by an unprecedented increase in EV sales (green line), reaching approximately 93.7 thousand EVs over the entire period. Nine times as many vehicles were introduced into the market when compared to the longer R&D period. This relatively high EV sales volume supports the finding by Magnusson and Berggren (2011) that some car manufacturers perceived EVs as a commercially viable opportunity during this period. Because of its unprecedented increase in EV sales we label this period the commercialization period.

The remainder of this section focuses on the differences between the R&D period and the commercialization period, in terms of the car manufacturers' incentive and opportunity to innovate and in terms of their business strategies. The period of inactivity has been omitted from further analysis, because it is relatively insignificant in terms of EV developments.

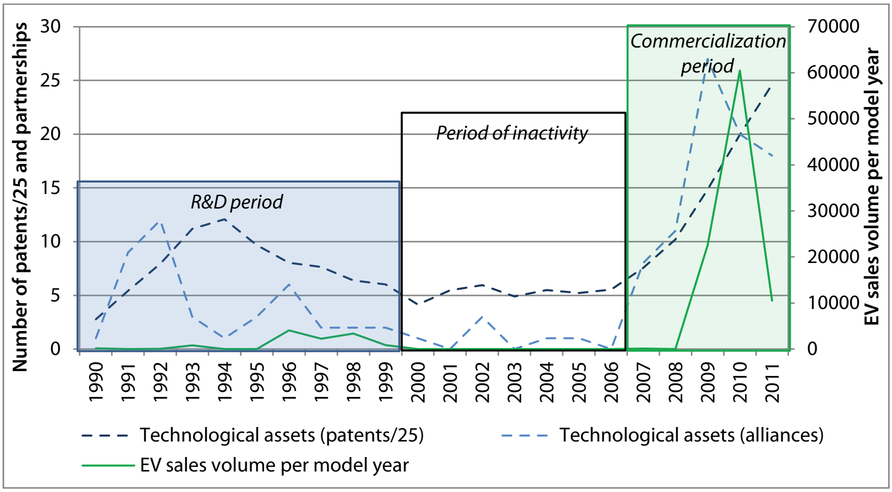


Figure 3.1, Trends in R&D and commercialization over the period 1990-2011

3.4.2 Statistical analyses: Hypotheses 1 and 2

Table 3.2 displays the results of our Mann-Whitney tests on the differences between groups as formulated in our hypotheses. The first two rows of results relate to the R&D period; the third row to the commercialization period. With regard to hypothesis 1, Large car manufacturers that fell under the full ZEV mandate will have a) developed a stronger opportunity to innovate and b) will have marketed more EVs during the 1990s than large car manufacturers that did not fall under this mandate, Table 3.2 shows that there is a significant difference between the groups in terms of the asset position during the R&D period ($p<0.05$). No similar differences in asset position were found during the commercialization period. Therefore, hypothesis 1a can be confirmed, indicating that the CARB succeeded in stimulating firms falling under the full ZEV mandate to develop EV technology, and thus to increase their EV asset position. Moreover, the positive effect of the mandate on the asset position of these firms did not continue in the commercialization period. Hypothesis 1b is rejected, as no significant difference between groups could be identified in terms of EV sales. This suggests that although the CARB succeeded in temporarily triggering EV asset position development by the firms that fell under the full ZEV mandate, it was not able to increase the firms' EV sales in the R&D period.

With regard to hypothesis 2, Large car manufacturers that have a stronger incentive and opportunity to innovate, will have marketed more EVs than their competitors during the early stage of EV commercialization, Table 3.2 shows that indeed a significant difference ($p<0.01$; Mann-Whitney U= 2.00) was found in EV sales volume during the commercialization period between, on the one hand, firms with above average asset position and below average net income and, on the other hand, the firms with below average asset position and/or above average net income. No significant difference was found during the R&D period. Moreover, at no time do groups, distinguished in terms of asset position or in net income alone, show any significant difference in EV sales. This confirms hypothesis 2 and suggests that large car manufacturers indeed are more inclined to move first in mass marketing EVs when they both have the incentive, i.e. they are less profitable in the ICEV regime, and the opportunity, i.e. they have a high EV asset position. Lack of profitability in the ICEV regime or a strong asset position alone does not suffice to trigger a large car manufacturer to move first in mass marketing EVs.

Table 3.2, Between group statistics of the Mann-Whitney tests.

Differences between groups for R&D period						
Dependent Variable:	Group variable:	N	Mean	Mann-Whitney U	Z score	Exact sig. (1-tailed)
Asset Position	Falling Under CARB's full ZEV mandate	6	.7621	11.00	-1.886	0.033
		9	-.5080			
EV Sales Volume	Falling Under CARB's full ZEV mandate	6	94.62	17.00	-1.205	0.129
		9	66.11			
Differences between groups for the commercialization period						
Dependent Variable:	Group variable:	N	Mean	Mann-Whitney U	Z score	Exact sig. (1-tailed)
EV Sales Volume	High Asset Position and Low Net Income	3	4168	2.00	-2.505	0.009
		12	519.4			

3.4.3 Clustering of business strategies

Figure 3.2 provides a firm level overview of the data, along the dimensions of incentive to innovate, measured by net income (y-axis); opportunity to innovate, measured by EV asset position (x-axis); and business strategy, measured by EV sales volume (bubble size, with different scales per period; with empty bubbles if no EVs were sold). The bold lines represent the averages in terms of net income and asset position, over the population of large car manufacturers. Based on these averages, the data have been clustered into four quadrants.

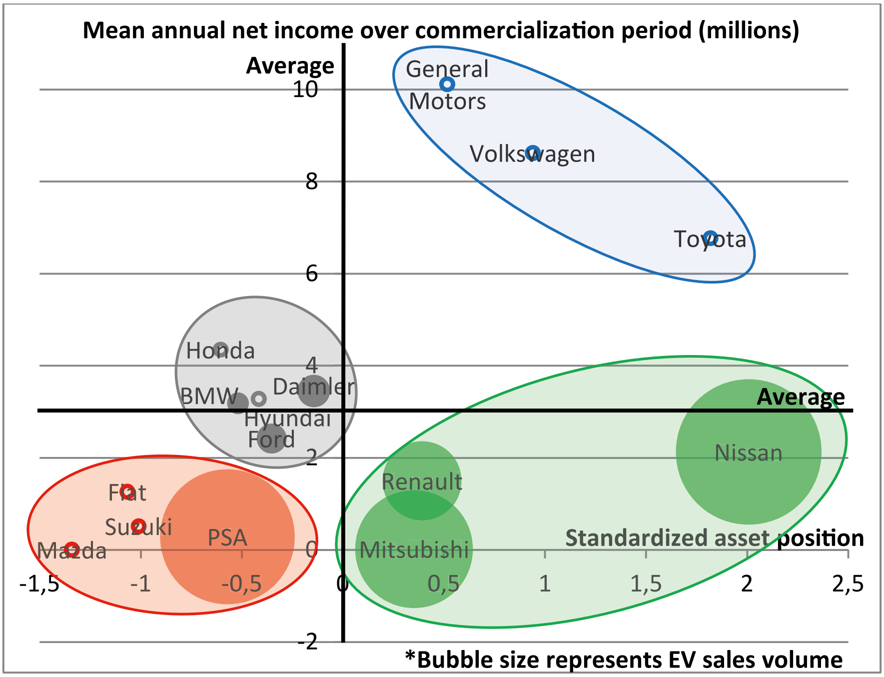


Figure 3.2, firm level distribution during the commercialization period

The lower left cluster in Figure 3.2 comprises firms that have a high incentive to innovate (below average profitability), but little opportunity to innovate (below average EV asset position). The business strategies of these firms can be characterized as laggard strategies as most of these firms did not intend to commercialize EVs in the short term. As of late 2012, Suzuki has no plans whatsoever to exploit EVs, Mazda is postponing EV exploitation until 2018 (Newton, 2011) and Fiat has planned only a restricted market introduction of its EVs in California (Fiat, 2013). PSA is a special case in this cluster, as it leveraged the asset positions of other car manufacturers to sell approximately 27,5 thousand EVs by the end of 2012. PSA circumvented its low EV asset position by buying and reselling ready-made EVs from Mitsubishi and by using Venturi Automobiles' capabilities to transform PSA's existing vans into EVs (PSA Peugeot Citroën, 2008; 2012; 2013).

The upper right cluster consists of firms that have little incentive and a strong opportunity to exploit EVs. These firms provided no EVs during the commercialization period, suggesting they also employed a laggard strategy in this period. Toyota explained that it wants to exploit the gradual electrification of the ICEV, enjoying knowledge spill-overs between each step (Toyota, 2012). Volkswagen wants to adopt a 'slow follower EV strategy' and waits for the system to materialize before they attempt to exploit EVs (Volkswagen, 2012). General Motors wanted to mimic the success of the Prius using plug-in hybrid electric vehicles; it leveraged its EV asset position to introduce this plug-in hybrid car to the market (General Motors, 2012).

The central cluster comprises firms with average incentive and some opportunity to innovate. The EV strategies of these firms are mixed. BMW, Ford, Honda and Daimler are all experimenting with or starting the market introduction of their EVs (BMW, 2013; Daimler, 2013; Ford, 2013; Honda, 2013), whereas Hyundai focuses only on the introduction of Hydrogen Fuel Cell Vehicles (Hyundai Motors, 2011), another zero-emission and radically-innovative vehicle. During the commercialization period, the central cluster overall is closer to marketing their EVs than the firms in the upper right and the lower left cluster (with the exception of PSA), while being less exploitative than the lower right cluster. We classify the firms in the central cluster therefore as quick followers.

The firms in the lower right cluster have a high incentive to innovate as well as a strong asset position. In accordance with confirmed hypothesis 2, each of these firms has introduced a large number of EVs compared to other car manufacturers. Their business strategy is therefore classified as a first mover strategy. Mitsubishi quickly developed a strong asset position during the commercialization period, which enabled it to pioneer in mass marketing EVs (Mitsubishi Corporation, 2011). In a contractual agreement PSA initially ordered 100.000 EVs from Mitsubishi (Roberts, 2012). Renault engaged in a partnership with Nissan, which already had a strong asset position during the R&D period, to jointly exploit the commercialization of EVs. Nissan used its strong asset position to commercially exploit the first purpose-built EV, selling approximately 32 thousand models by the end of 2012 (Nissan Global, 2013). Renault had a more diversified strategy towards marketing EVs and launched four very different models on the market between late 2010 and 2013.

In conclusion, we find that first movers (lower right cluster) have a high incentive and opportunity to innovate, while quick followers (central cluster) have some incentive and some opportunity to innovate. Moreover, two types of laggards can be identified. The lower left cluster generally comprised laggards with high incentive to innovate, but with little opportunity. The upper right cluster comprised laggards with no incentive to innovate, but with sufficient opportunity.

3.5 Discussion

In this Discussion Section we highlight the contributions made in this chapter, suggest some areas for future research and provide several policy and business strategy recommendations.

3.5.1 Contributions and Future Research Suggestions

This chapter contributes to the literature on innovation by incumbent firms, by explaining differences in the introduction of a radical innovation by incumbents, using the concepts of incentive and opportunity to innovate. Previous studies used these concepts only to explain differences in radical innovativeness between incumbents and new entrants (Chandy and Tellis, 2000; Henderson, 1993). We have shown that the incentive and opportunity to innovate explain differences in the exploitation of EVs between different incumbents and that radical innovation comes especially from the less profitable firms. Another contribution of this chapter is that we interpret the opportunity to innovate in terms of firms' asset positions, based on an extensive set of data on patent applications, partnerships, and prototypes, instead of firms' access to financial funds. This chapter contributes to the strategic management literature on business strategies, by linking the opportunity and incentive to innovate to business strategy and refining the business strategy typology by distinguishing between laggards with an incentive to innovate but no opportunity, and laggards with an opportunity to innovate and no incentive.

In addition to these contributions, this chapter also has several limitations that may highlight interesting areas for future research. First, firms may exhibit differences in their tendencies to patent and their willingness to publish strategic decisions. This could have affected our patent and our media statements database. Therefore, our findings must be carefully interpreted. Future developments that account for these firm level differences provide a fruitful area for further research. Second, we have labeled the period 2007-2011 a period of EV commercialization, but we do not imply that the EV has been successfully commercialized. We only argue that the commercialization of the EV has been initiated. To illustrate, the best-selling EV sold approximately 32.000 units by the end of 2012, equaling 0.05% of 2011's annual personal vehicle sales (OICA, 2011). Third, we cannot explain why firms falling under the full ZEV mandate did not have significantly higher EV sales than the other firms during this period, despite their higher opportunity to innovate. Car manufacturers may have attempted to strategically keep their EV sales low while lobbying against the ZEV mandate, arguing there would not be sufficient demand for EVs (Collantes and Sperling, 2008; Boschert, 2006). Further research should consider this context of lobbying activities. Finally, future research could also address collaboration activities of incumbents – an important means to obtain assets (Halme and Korpela, 2013). We found that PSA had unexpectedly high sales despite their relatively low opportunity to innovate, because they relied on the asset position of other car manufacturers to market EVs. We recommend further research to focus more explicitly on the decision to develop assets internally or to access them externally, and study how this affects the opportunity to innovate and the business strategy.

3.5.2 Policy Recommendations

This study found that although the technology-push ZEV mandate resulted in more EV asset development, it was not successful in getting more EVs on the market in the 1990s. Moreover, we found that firms that are unsuccessful in the ICEV regime are the ones to mass market EVs because they have the incentive to do so. Based on these findings, we recommend policy makers to complement technology-push regulations with demand-pull regulations that focus on shaping public and customer opinion (Oberhofer and Fürst, 2013), providing financial, infrastructural and other supporting regulations like preferential parking and carpool lane access (Firnkorn and Müller, 2012). Such supportive complementary regulations will enhance the economic viability of currently less profitable firms by improving EV sales on which these firms may become more dependent. These policy measures support the less profitable firms in their possibly risky EV strategy, and thereby reduce the firms' chance to fail and their need to apply for government bailouts. These policy measures will also support the transition towards a sustainable automotive transportation system based on a larger share of EVs. Moreover, such regulations will drive firms' sustainable strategies (Ervin et al., 2013) and may prevent non-compliance and defensive behavior (Pedersen et al., 2013; Smink et al., 2013) towards stand-alone technology-push policies that force firms to sell products that lack demand.

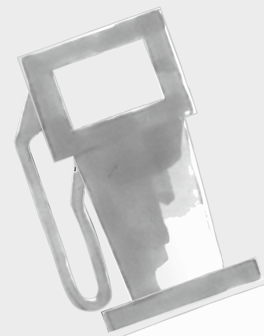
3.5.3 Business Strategy Recommendations

This study indicated that the less profitable firms in the ICEV regime that have a strong EV asset position are mass marketing EVs. So far, however, EV sales have been low. To increase EV demand, car manufacturers may want to step up their lobbying for more EV supporting regulations, like the ones discussed above. Another way of reducing risks, by minimizing costs of investment and promoting industry standards in the small emerging EV market, is to engage in more collaboration (Gold et al. 2010; Halme and Korpela, 2013; Harms et al. 2013) – a strategy employed in the Nissan-Renault alliance and the EV-contract between Mitsubishi and PSA. We advise the more profitable firms that lack EV commercialization incentives to continue building their EV asset position. This enables them to enter the EV market quickly and prevent losing large market share when the EV market takes off. An effective way to build this EV asset position would be to collaborate with first movers, which allows the more profitable firms to stay on top of contemporary developments and determine when to enter the EV market.

These recommendations can be generalized to firms pioneering in sustainable development in an attempt to outcompete their rivals. To enhance the success of their investments, these firms should lobby for environmental policy that supports demand for sustainable innovations. Additionally, when investment costs are high and demand is still low, collaboration between innovators may serve to reduce costs and promote the creation of industry standards (Harms et al. 2013; Sampson 2005).

3.6 Conclusion

In this study, we analyzed the incentive and opportunity to innovate of large car manufacturers and their strategies to market EVs over the period 1990-2011. We proposed that firms with a stronger incentive and a stronger opportunity to innovate introduce more EVs into the market. The incentive to innovate is measured by a firm's income in the ICEV regime, and the opportunity to innovate by a firm's EV asset position. We find that during the EV's R&D period in the 1990s, regulatory pressures triggered large car manufacturers to develop EV related assets. Although this constitutes an increase in their opportunity to innovate, it did not result in significantly higher EV sales. As of 2007, during the EV's commercialization period, large car manufacturers with a strong opportunity and a strong incentive to innovate, i.e. firms with below average net income and an above average asset position, have significantly higher EV sales than firms with either a low incentive and/or a low opportunity to innovate. Firms with a strong opportunity and a strong incentive to innovate adopted a first-mover strategy. Large car manufacturers with some incentive and opportunity to innovate tended to pursue a quick follower strategy, whereas firms with either little incentive or little opportunity followed a laggard strategy. In this chapter we make important contributions to the literature on business strategy by explaining why some incumbents radically innovate and others do not, and by refining the business strategy typology in several ways: we relate the different business strategies to firms' opportunity and incentive to innovate, and we distinguish between laggards that have no incentive and laggards that have no opportunity to innovate. We contribute to methodology by providing new ways of operationalizing the opportunity to innovate. We provide recommendations for policy makers to effectively stimulate sustainable development and for incumbents to successfully engage in sustainable innovation.



4 Car manufacturers' changing political strategies on the ZEV mandate

Abstract

We ask how incumbent car manufacturers and their political coalitions changed their political strategy with respect to the Californian zero emission vehicle mandate over the period 2000–2013. Building on the Corporate Political Activities literature we conceptualize firms' political strategies and their underlying tactics and actions. Our longitudinal case study builds on a dataset comprising governmental reports, documents, and public hearing transcripts, letters from industry, and complementary interviews with stakeholders. We find that car manufacturers became less defensive over time and more proactive and compliant in their political strategies towards the zero emission vehicle mandate. Car manufacturers' coalitions on the other hand, remain relatively defensive in their political actions as they continue to do the manufacturers' "dirty work". We provide insights in the Corporate Political Activities used to influence policymakers. To deal with industry opposition to policy interventions, our research suggests that policy makers might focus their interaction with industry on individual firms instead of industry associations, craft policies that stimulate competition between firms to break apart their closed industry front, and complement technology-forcing policies with demand-pull initiatives.

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4.1 Introduction

The transition to zero emission vehicles (ZEVs), especially electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs)[7], will play an important role in creating more sustainable automotive transportation systems (Sperling and Gordon, 2009; Lutsey and Sperling, 2009; Wang et al., 2008). Because ZEV technologies are radically different from internal combustion engines, the longtime core technology for automotive companies, they constitute competence-destroying innovations to incumbent manufacturers. Chapter 3 showed that this competence-destroying nature of EVs and HFCVs reduces car manufacturers' incentive to invest in and commercialize ZEVs. Therefore, policy intervention is important to support a transition towards such sustainable technologies (Van der Vooren et al., 2013; Lutsey and Sperling, 2010).

However, incumbent car manufacturers have a history of opposing such interventions because it pushes them away from their longtime core technologies (Penna and Geels, 2013; Doyle, 2000; Collantes and Sperling, 2008). Despite their longtime investments in internal combustion engines and because of policy interventions, some car manufacturers have started mass commercializing electric vehicles after 2009 (Wesseling et al., 2014b; Wells and Nieuwenhuis, 2012). Our overall hypothesis is that this change in strategy would be supported by a corresponding change in political strategy, i.e. becoming less opposed to ZEV-forcing regulations, which in turn makes it easier for policymakers to implement ZEV policies.

The Corporate Political Activities (CPA) literature studies the political strategies of firms, and the various tactics they employ, to influence policy intervention (Oliver and Holzinger, 2008). CPAs are defined as "corporate attempts to shape government policy in ways favorable to the firm" (Hillman et al., 2004, p. 838; Baysinger, 1984). The term 'action' is defined more broadly as any corporate response to policy intervention, including both influence and non-influence. We apply the CPA literature's concepts and operationalization methods to study the political strategies, tactics, and actions employed by large car manufacturers in response to policy intervention. We add to the CPA literature by 1) applying CPA concepts to sustainable transitions in the automotive transportation sector, which so far has only been studied from different socio-political perspectives

7 For an overview of acronyms see the List of Abreviations at the end of this dissertation.

(Penna and Geels, 2013), and 2) researching how CPAs change over time, as "[o]ur least complete understandings revolve around the ways that CPA changes over time" (Getz, 1997, p.64).

We focus on the political strategies of car manufacturers toward the ZEV mandate adopted by the California Air Resources Board (CARB). This mandate, first adopted in 1990, is a radical policy action in the sense that it forces new low and zero emission vehicle technologies into the market (Collantes and Sperling, 2008). In the 1990s, car manufacturers used various tactics to block and modify the ZEV mandate, including information tactics such as lobbying CARB (Collantes and Sperling, 2008), co-constructing the meaning of what ZEV technology is (Fogelberg, 2000), and constituency-building tactics such as the Alliance of Automobile Manufacturers (AAM) hiring "public relations firm Cerrell Associates … to turn public sentiment against the ZEV mandate" (Boschert, 2006, p.18). Because our aim is to study if this defensive political strategy of car manufacturers has changed since the 1990s we focus on the timeframe 2000-2013. During this period four ZEV mandate amendments were adopted.

We investigate the nature and magnitude of the change in the political strategies of large car manufacturers and their coalitions toward the ZEV mandate, distinguishing between individual and collective political strategies of manufacturers. We highlight the types of political tactics and actions that support these strategies. Using these insights, we suggest how policymakers may engage more productively and effectively with businesses to implement policy interventions.

4.2 Conceptual framework

The Corporate Political Activities (CPA) literature argues that in strongly regulated environments, firms may strengthen their competitive advantage by engaging in political strategies (Hillman and Hitt, 1999; Oliver and Holzinger, 2008). Consequently, 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 gain value (Oliver and Holzinger, 2008).

4.2.1 Categorizing political strategies

Firms create value by improving their economic performance through political actions (Lux et al., 2011; Mathur and Singh, 2011; Lawton et al., 2013; Hillman & Hitt, 1999). The Resource Based View perceives the firm's assets as the base of its competitive position and stresses that value arises from using internal resources to exploit opportunities in the firm's environment (Barney, 1991). Accordingly, the CPA literature argues that firms may attempt to shape their political environment to maintain or create value (Oliver and Holzinger, 2008; Buysse and Verbeke, 2003). Value maintenance refers to maintaining the status quo, while value creation refers to exploiting early mover advantages.

Besides value maintenance and creation, the CPA literature tends to differentiate between active influence on, and passive compliance with government regulations (Carroll, 1979; Buysse and Verbeke, 2003; Boddewyn and Brewer, 1994). In line with Oliver and Holzinger (2008, p. 505), we define political compliance strategies as "firm-level actions undertaken in conformity with political requirements and expectations for the purpose of maintaining or creating value by anticipating or adapting to public policy," and political influence strategies as "firm-level actions undertaken for the purpose of mobilizing support for the firm's interests".

Based on the distinction between value creation and maintenance, and compliance and influence, a 2 by 2 matrix of political strategies can be constructed, as shown in Table 4.1. Compliance strategies focus on (re)shaping the internal resources to comply with existing or anticipated regulations. Firms employing a reactive compliance strategy aim to maintain the value of their resources and competences by aligning them efficiently and effectively with regulatory demands (Carroll, 1979; Buysse and Verbeke, 2003; Oliver and Holzinger, 2008). Firms with an anticipatory compliance strategy anticipate regulatory changes to create value and exploit early-mover advantages by aligning their resources and competences with anticipated regulatory demands (Ibid.). Political influence strategies utilize CPAs to shape regulation, either to maintain value in a defensive political strategy, or to create value in a proactive strategy. Firms engaging in defensive political strategies oppose regulations, like the ZEV mandate, that threaten their firm's value; they are trying to maintain the favorable status quo (Schaffer et al., 2000; Oliver and Holzinger, 2008; Stenzel and Frenzel, 2008; Hillman et al., 2004; Carroll, 1979). Proactive political strategies are intended to shape regulations so that they support the firm's creation of new value and enhance their first mover advantages (Carroll, 1979; Buysse and Verbeke, 2003; Oliver and Holzinger, 2008).

Applying this categorization to our case study, car manufacturers that yield value from their core technology resources and competences have incentive to maintain the status quo and may adopt defensive strategies to oppose the ZEV mandate. Nevertheless, Chapter 2 showed that strong competition stimulates investments in various sustainable vehicle technologies and Chapter 3 indicated that some manufacturers are attempting to create new value and build up a competitive advantage through radical innovations like EVs. Chapter 3 argues that by focusing on radical innovation, they try to shift the competitive focus from the incumbent core technology in which they are less successful, to the new technology in which they may have built up competitive advantage. These innovative firms may engage in proactive political strategies towards the ZEV mandate to support the value creating strategies through which they comply with the mandate and further enhance their competitive advantage.

We add to CPA literature by broadening the political strategy typology and distinguish between general proactive CPAs that are technology-neutral and thus benefit all car manufacturers alike, and competitive proactive CPAs that are technology-specific and thus benefit only the car manufacturers investing in this technology. To support their compliance strategy, car manufacturers complying for example through EVs, may competitively lobby in favor of EVs instead of ZEV technologies in general. To further enhance the competitive advantage of their compliance strategy, they may also counter the competitive proactive lobby of car manufacturers in other technology areas. Because different car manufacturers are betting on different technologies and are thus engaged in technological competition – see Chapter 2, they may also be competing in their proactive political strategies for regulatory support for the technologies they invested in and complying through. Hence, the strong competition in this scetor may not only result in competitive compliance strategies as found in Chapter 2 and 3, but also in competitive proactive influence strategies.

Table 4.1, Types of political strategies, adapted from Oliver and Holzinger (2008)

		Value perspective	
		Value maintenance	**Value creation**
Strategic orientation	Compliance	**Reactive strategy.** *Focus on reconfiguring internal processes*	**Anticipatory strategy.** *Focus on scanning the firm's environment*
	Political Influence	**Defensive strategy.** *Focus on influencing policymakers to retain status quo; opposing policy interventions that change the status quo*	**General and Competitive proactive strategy.** *Focus on influencing policymakers to enact favorable regulatory changes*

Over the past 15 years, car manufacturers have become increasingly active in commercializing low and zero emission vehicles, trying to gain a competitive advantage in this field (Pohl and Yarime, 2012; Wells and Nieuwenhuis, 2012; Wesseling et al., 2014b). Literature indicates that firms also engage in CPAs to gain competitive advantage (Lux et al., 2011; Mathur and Singh, 2011; Lawton et al., 2013; Hillman et al., 2004). We expect that when car manufacturers have limited access to market-ready compliance technologies, they will protect their incumbent technology investments by opposing technology-forcing regulations that force them away from their incumbent technology. However, as car manufacturers increasingly gain access to these compliance technologies, we expect that they will replace their defensive political influence strategy with a more proactive influence strategy to ease compliance for the technologies they are investing in, thereby reducing their compliance costs and gaining a competitive advantage over rivals that comply through other technologies. Hence, over time, car manufacturers' political strategies will become less defensive to the ZEV mandate and more proactive to support their compliance strategies. Based on these notions we formulate hypothesis 1.

Hypothesis 1: Throughout the timeframe 2000-2013, car manufacturers became less defensive and more proactive in their political strategies towards the ZEV mandate.

4.2.2 Tactics underpinning political influence strategies

Public policy making can be described as a market with mutually interdependent policy makers and interest groups (Hillman and Hitt, 1999). Interest groups are dependent on policy makers because they have specific policy preferences. Policy makers on the other hand desire support for their policy like information and legal support to "ensure that their policies are effective and enforceable" (Hultén et al., 2012, p. 354). Moreover, policy makers desire direct personal incentives such as constituent and financial support for their re-election and financing of political campaigns (Ibid.).

Through various tactics, car manufacturers exploit policy makers' dependence on these resources to effectuate their political influence strategies. We identify information, financial, litigation, constituency-building and political connectedness tactics (Hillman and Hitt, 1999; Mathur and Singh, 2011). Each tactic may encompass different CPAs.

Information tactics aim to provide policymakers with arguments that will affect their policy decisions, like statements on the costs and benefits of policy (Aplin and Hegarty, 1980). This group of CPA tactics includes lobbying[8], commissioning or conducting research to support arguments, having experts testify in hearings or court, and providing position papers (Hillman and Hitt, 1999; Hillman et al., 2004; Kolk and Pinske, 2007; Mathur and Singh, 2011).

Financial tactics attempt to influence public policy by providing financial incentives to policymakers (Hillman and Hitt, 1999; Lord, 2000; Aplin and Hegarty, 1980). This tactic includes financial contributions to policymakers, political parties, and Political Action Committees, honoraria for speaking, and paying for travel expenses (Hillman and Hitt, 1999; Lord, 2000; Mathur and Singh, 2011). Information and financial tactics tend to be strongly related, as firms often employ both (Schuler et al., 2002; Ansolabehere et al., 2002).

Litigation tactics, i.e. taking legal action, can be used to challenge public policy in court, but this tactic can only be used when the firm can show reasonable

8 In concurrence with definitions maintained by US state governments, we define lobbying broadly to mean directly or indirectly communicating with any government employee for the purpose of influencing legislative or administrative actions (NCSL, 2013). Our definition is not limited to those receiving compensation or reimbursement from a third party to lobby, and/or those officially registered as lobbyists (NCSL, 2013).

cause to be concerned with the issue (Getz, 1997). If challenged successfully (at the highest court of appeal), policy makers are legally forced to change their policy.

Constituency-building tactics are meant to influence politicians through the votes on which they depend for re-election. Such tactics include advocacy advertising, grassroots mobilization and astroturfing (Hillman and Hitt, 1999; Lord, 2003). Astroturfing refers to fake grassroots mobilization funded by large corporations to create constituency in their favor (Cho et al., 2011).

Political connectedness tactics enhance lobbying by providing firms direct access to relevant policy channels (Oliver and Holzinger, 2008; Mathur and Singh, 2011). Firms often attain these advantages by employing ex-policymakers (Goldman et al., 2009; Faccio et al., 2006; Agrawal and Knoeber, 2001).

4.2.3 Coalitions

CPA tactics are further categorized in terms of individual or collective actions (Hillman et al., 2004; Hillman and Hitt, 1999; Olson, 1965; Yoffie, 1987; Bonardi et al. 2005). Industry associations such as the AAM and Global Automakers (GA) and other lobbying coalitions are collective groups that represent the interests of their members by engaging in political strategies; in this chapter we refer to such groups as coalitions. The decision to engage in CPAs individually or collectively has been frequently studied. The main advantages of collective action include reduced cost per firm and the potential for enhanced success as actions are supported by a larger group and therefore carry more weight (Chong, 1991; Jia, 2014; Olson, 1965; Vining et al., 2005). Only Hillman and Hitt (1999) noted that when it comes to opposing sensitive policy issues, like climate change and public health, collective actions limit the exposure and liability of members when coalitions lose a political battle. The ZEV mandate that we study is linked to both climate change and public health, two issues that have become increasingly politically sensitive over recent years (Schmidt et al., 2013), suggesting that opposition against the mandate may come increasingly from coalitions. A disadvantage of collective action is that the individual firm is less able to influence policy to meet its specific individual needs (Hillman and Hitt, 1999; Jia, 2014; Vining et al., 2005), such as promoting specific technologies within the ZEV mandate, implying that competitive proactive CPAs are less expected by coalitions. . On these grounds, we formulate hypothesis 2.

Hypothesis 2: Throughout the timeframe 2000-2013, industry associations and lobby coalitions continued to be more defensive in their political strategy than their member car manufacturers by opposing the ZEV mandate more strongly.

4.3 Methods

4.3.1 Operationalization

To study the changes in car manufacturers' and coalitions' political strategies, we study all their actions in response to the ZEV mandate over the timeframe 2000-2013. Based on its goal, each action is attributed to a political strategy. The introduction of mandated ZEVs and statements of support, i.e. statements that neither oppose nor shape the mandate, are indicative of a compliance strategy. Because we cannot distinguish between reactive and anticipatory compliance strategies on the basis of these indicators, we refer to them in aggregate as "compliance strategies".

Political influence strategies are operationalized through CPAs. Categorized according to different tactics, Table 4.2 operationalizes the CPAs included at the outset of this study. CPAs aiming to oppose the ZEV mandate were counted as part of a defensive political influence strategy, while CPAs attempting to influence the ZEV mandate in such a way that it creates value for all car manufacturers or only for a few, were counted as general and competitive proactive strategies respectively. Coalition formation is included as an extra dimension of political influence strategies, and is measured by whether CPAs were conducted individually or collectively.

Finally, we used the number of CPAs by car manufacturers and their coalitions and the organizations they funded to engage in CPAs on their behalf, as complementary indicators for the level of political influence strategy (i.e., many CPAs indicate a stronger political influence strategy, whereas a few indicate little interaction with government and thus more of a compliance strategy).

Table 4.2, Database and operationalization scheme

Database		Indicators of response actions		Strategy
Interviews	CARB employees (6); EPA employee (1); car manufacturer representatives (7); ZEV advocates (2)	Compliance actions	Sales data Statements of support	Compliance strategy
Public hearings	5 Public hearing transcripts	*Political influence tactics*		
Letters to CARB and EPA	61 Letters to CARB and 22 to letters EPA	Information	Arguments provided, studies commissioned, expert testimonies	Defensive influence strategy
CARB documents	263 Documents, including Final and Initial 'Statements of Reason'; Technical reviews; Litigation documents.	Financial	Honoraria for speaking and paying for travel expenses	
		Legal	Lawsuits filed	General proactive influence strategy
Complementary sources	Websites, literature, documents, vehicle-type built data sheets from CARB	Political connectedness	Ex-policymakers and ex-politicians employed	
		Constituency building	Engagement in grassroots mobilization and astroturfing; influencing the public through advertising	Competitive proactive influence strategy

4.3.2 Data collection

To identify the actions of car manufacturers and their coalitions, we analyzed the content of various data sources, see Table 4.2 for an overview. CARB has an extensive database of documents related to the ZEV mandate available on their website. These documents provided a comprehensive database and a good indication of the actions undertaken by industry actors because they cover most issues related to the mandate, including for example litigation and introduction of ZEVs. All these documents related to the timeframe of study were included in our analysis. The "Final Statements of Reason" documents provided the core for the Results section because they incorporate lobbying comments from public hearings and from letters sent to CARB that were not available throughout the entire period of study. We also included letters to the US Environmental Protection Agency (EPA) on their decision to waive federal preemption, which is required for CARB to enforce the ZEV mandate.

A drawback of this database is that it does not include the initial behind-closed-doors lobbying (Interviewee 1). To partially account for this drawback and to collect data on financial and political connectedness and constituency-building tactics, we conducted 16 semi-structured interviews with representatives of car manufacturers and their associations, with ZEV advocates and with policymakers, all of whom were frequently involved in the ZEV mandate, to complement our data. We sent the interviewees the results of this study to verify our interpretation of their answers. Although some car manufacturer representatives were reluctant to discuss their influence tactics in-depth, CARB employees and ZEV advocates confronted by these tactics were not. To facilitate candid responses, all interviewees were granted anonymity for this study.

Complementary data from professional websites, news articles and reports were obtained using snowballing methods. These data were only used to triangulate and uncover the specifics of car manufacturers' and coalitions' actions in response to the ZEV mandate, not to identify new actions.

4.3.3 Methods of analysis

Using content analysis on our database, we identified the actions car manufacturers and their coalitions used in response to the ZEV mandate. Since we applied an existing theoretical framework on political strategies to our data, we used a priori coding (Weber, 1990) – based on the previously discussed operationalization categories, to determine what data belonged to which political strategy, i.e. compliance, defensive, general proactive and competitive proactive political strategies. We checked for inter-coder reliability by having another researcher, not involved in the study, check our coding scheme. Our Krippendorff's alpha of 0.878 indicates the two coders have interpreted the data similarly (Krippendorff, 2004). In line with Weber (1990) we left room to slightly revise and tighten up these categories, in case coders disagreed.

To qualitatively study changes in political strategies, all actions – each attributed to a single political strategy – were mapped out over time.

4.4 Analysis

Text box 1 describes the policy processes around the ZEV mandate and summarizes the 2001, 2003, 2008 and 2012 ZEV amendments that are the focus of our analysis. Subsections 4.1 through 4.4 describe the political strategies and associated CPAs of car manufacturers and their coalitions toward the four amendments. These CPAs are summarized in Tables 4.3 and 4.4. A fifth subsection provides a longitudinal analysis of the four periods, based on a reflection of the discussed CPAs and based on Figures 4.1 and 4.2 that resulted from our content analysis.

Text box 1 – the ZEV mandate. The Federal Clean Air Act provides California the power to issue vehicle emission standards that are more stringent than the federal standards (CARB, 2001a). CARB is the regulatory body that issued the ZEV mandate, which requires car manufacturers to sell low and zero emission vehicles in proportion to their total vehicle sales in California (CARB, 2001a). To meet this mandated level, car manufacturers gain different levels of credit for the different low and zero emission vehicles sold (CARB, 2012a). To enforce these standards, EPA needs to waive federal preemption, as federal law supersedes any state jurisdiction on automotive emissions (EPA, 2006). Over time the ZEV mandate, first issued in 1990, was relaxed through a series of amendments that allow more low and zero emission vehicle technologies to be included against higher credits. The 2012 amendments were the first to increase stringency. To guarantee political support for the amendments, CARB interacts with key stakeholders, including industry representatives, environmental interest groups and municipalities. Section 177 of the Clean Air Act allows other states to adopt California's ZEV standards. Ten states other than California had adopted the 2012 amendments (CARB, 2012a), of which New Mexico withdrew in December 2013.

This study focuses on amendments from 2000 to 2013, including the 2001, 2003, 2008 and 2012 amendments. The 2001 ZEV amendments further relaxed the ZEV mandate and increased flexibility by allowing hybrid electric vehicles (HEVs) and very clean internal combustion engine vehicles to meet part of the ZEV sales requirements. Additionally, credit multipliers were introduced for early introduction, increased range and improved vehicle efficiency, and heavier light trucks, SUVs and minivans were included in the ZEV mandate, because of their increasing market share (Interviewees 2; 3). The 2003 ZEV amendments resulted from lawsuits filed by industry in 2002. The amendments further relaxed and increased flexibility by 1) delaying ZEV requirements by two years; 2) including an alternative compliance path whereby a limited number of HFCVs would be sufficient to meet the ZEV requirements; and 3) offering credit multipliers for many ZEV technologies. The 2008 ZEV amendments provided further relaxation and flexibility by: 1) allowing plug-in hybrid electric vehicles (PHEVs) to meet part of the ZEV sales requirements; 2) allowing EVs to comply via the alternative compliance path that previously applied only to HFCVs. The 2012 ZEV amendments, part of CARB's broader program to reduce GHG and local pollutant emissions, represented the first amendments that were more stringent than their predecessor, greatly increasing ZEV sales requirements for model years 2018 through 2025. These amendments included: 1) an option that allowed companies who over-complied with their greenhouse gas emission requirements in the Clean Cars program to offset up to half their ZEV requirement for 2018 through 2021; 2) new, simplified technology categories that replaced old ones; 3) eliminated the advanced internal combustion engine vehicles category; and 4) discontinued the "travel provision" for EVs beginning in 2018, whereby car manufacturers could sell EVs in non-California states and earn credit toward the California ZEV requirements (resulting in car manufacturers needing to more than double ZEV sales).

4.4.1 The 2001 rulemaking

The political strategies of car manufacturers and coalitions with respect to the 2001 ZEV amendments were predominantly defensive, as shown in Tables 4.3 and 4.4. The following subsections discuss in-depth their defensive, compliance and proactive CPAs.

Defensive CPAs

The defensive strategy comprised only information tactics during this period. One information tactic used by car manufacturers to oppose the mandate was to make EV demand seem smaller (CARB, 2000; Interviewee 2). EV availability was limited "due to the decision by most manufacturers to curtail production after placing [on the market] the vehicles required for their [agreed-upon 'Memorandum Of Agreement'] demonstration programs" (CARB, 2000, p.17). To make demand seem smaller, General Motors (GM) reportedly concealed their

EV waiting lists (Boschert, 2006). GM and Toyota funded a study that indicated that "the average consumer would not accept a RAV4 EV if it were offered for free" (CARB, 2000, p. 86). These actions made the already small EV demand (Interviewee 2) seem even smaller, and were used as an information tactic to undermine support for the ZEV mandate and to help justify a series of lawsuits against the mandate filed by GM, DaimlerChrysler and several car dealerships in 2001-2002 (Boschert, 2006).

A second information tactic was to propose alternatives to the ZEV mandate. Firstly, car manufacturers and the industry association AAM proposed a "Fair Market Test" to assess whether there would be a realistic prospect for a mass market in EVs, as a precondition for the ZEV mandate (CARB, 2001b). Secondly, industry commissioned consultancy firm AIR to develop an alternative program that would be more cost-effective and result in lower emission than the ZEV mandate (CARB, 2001a). Third, GM suggested an alternative program that focused on conventional vehicles to attain emission targets (CARB, 2001b). Through Sierra Research, another consultancy, car manufacturers also hired experts to testify at the public CARB hearings (Ibid.), representing third information tactic.

As a fourth information tactic, car manufacturers commissioned studies to attack the mandate (Interviewees 2; 3; 5). Two NERA/Sierra studies commissioned by GM argued that the ZEV mandate would result in higher overall fleet emissions, because the ZEV mandate would lead to more expensive new vehicles, leading to higher retention rates of older, more polluting vehicles (NERA and Sierra, 2001; CARB, 2001b). GM continued to conclude that CARB 'exceeded its legislative authority' by adopting a policy (the ZEV mandate) that increased emissions (CARB, 2001a, p. 78). The AAM commissioned a third study that led to 78 lobbying comments attacking CARB's assumptions and the reliability of their data, and demanding more data (CARB, 2001a; 2002b; NERA and Sierra, 2002). These extensive comments suggest an attempt to delay the regulatory process with multiple requests for data, representing a fifth information tactic.

Compliance and proactive CPAs

Car manufacturers' compliance strategies started to diverge as neighborhood electric vehicles (NEVs) emerged as a cheap alternative to EVs and HFCVs in complying with the ZEV mandate (Interviewees 5; 6; CARB, 2004). Consequently, NEVs and EVs became the dominant compliance strategies, as HFCVs were not ready for commercialization (see Table 4.3). To obtain early NEV credits, Ford and DaimlerChrysler acquired NEV producing companies Th!nk and GEM in 1999 and 2000, respectively (Interviewees 2; 3; 5). Because most NEVs were low speed, limited range EVs, they did not advance the state of EV technology nor market development, and thus CARB proposed to cap NEV credits (CARB, 2001a; Interviewees 5; 6). To support their compliance strategy, the US car manufacturers lobbied proactively to oppose this modification, arguing that they had "invested tens of millions of dollars, time, and effort to build and develop NEVs" (CARB, 2001a, p.173) and could not change their compliance strategy on short notice. Car manufacturers whose compliance strategy did not focus on NEVs, including Honda, opposed the NEV compliance option, stressing that NEVs did not comply with federal definitions and crash standards (CARB, 2001a). This case of competitive proactive lobbying on NEV credits suggests a strong relation between firms' compliance and political influence strategy.

Other examples of competitive proactive lobbying that underlie the relation between firms' compliance and political influence strategy are related to specific credit provisions and include the following: 1) GM opposing early HEV credits, while Toyota –leading in hybrids– supported them; 2) DaimlerChrysler opposing credits for re-leasing EVs which GM –exploiting these credits– supported; and 3) Toyota opposing credits for longer-range EVs that would benefit others (CARB, 2001a). These instances show how car manufacturers supported modifications that benefited their compliance strategy, while they opposed mandate modifications that yielded competitive advantage to their rivals.

4.4.2 The 2003 rulemaking

During the 2003 rulemaking the share of car manufacturers' proactive CPAs increased, although their strategies remained predominantly defensive (see Table 4.3). The political strategies of coalitions got even more defensive (see Table 4.4).

Defensive CPAs

Besides information tactics, car manufacturers also employed litigation tactics. Like with the 2001 rulemaking, the information tactic included commissioning studies to attack the ZEV mandate. One consultancy (AIR) focused on relaxation of the mandate and again proposed an alternative program to the mandate (CARB, 2003a; AIR, 2003). As in 2001, Sierra Research attacked the mandate's underlying assumptions, models and data and delayed the regulatory process with multiple requests for data. However, they now focused more strongly on the legal instead of technical aspects of the ZEV mandate, arguing it was illegitimate and that CARB needed to comply with its legal requirements (CARB, 2004; Sierra, 2003). Expert witnesses were called to oppose the mandate (Lyons, 2003; AIR, 2002).

As a litigation tactic, GM, DaimlerChrysler and dealerships filed three lawsuits (CARB, 2003). This was the only time that dealerships and car manufacturers cooperated to challenge the ZEV mandate. The Inclusion of dealers in the lawsuit allowed the car manufacturers to file the lawsuit in Fresno, known to be a "non-liberal court" (Interviewee 2). In this lawsuit, car manufacturers used ex-CARB employee Tom Austin (employed by consultancy Sierra Research) to testify against the ZEV mandate (Superior Court, 2002). These lawsuits can be perceived as an effective CPA, because they helped motivate CARB to adopt more relaxed and flexible amendments in 2003 (CARB, 2004; 2002a; Interviewee 2).

EPA did not waive federal pre-emption for the 1998, 2001 and 2003 ZEV amendments until 2006 (EPA, 2006). The AAM opposed a waiver using several legal arguments and by arguing that it would actually increase, not decrease, emissions because of the fleet-turnover effect (AAM, 2006; Interviewee 8). This opposition, together with changes in the ZEV mandate brought about by the lawsuits, significantly delayed the waiver process (Interviewees 2; 7; 8; 9).

Compliance and proactive CPAs

In the period up to the 2003 rulemaking, car manufacturers focused predominantly on NEVs and EVs in complying with the ZEV mandate (see Table 4.3). However, car manufacturers wanted the option to focus on HFCV commercialization, recognizing that it was further from commercialization (CARB, 2003b), and that they should not be required to pursue both technologies

(Interviewees 2; 3). EV supporters on the other hand, argued "that continued development of battery products provides a "safety net" in the event that fuel cell technology encounters impenetrable barriers" (CARB, 2003b, p. 9). Many EV advocates believed that CARB was favoring HFCVs (Interviewees 2; 10), and that car manufacturers used HFCV technology as a defensive distraction tactic to forestall EV commercialization (Interviewees 5; 10). Car manufacturers were proactively lobbying to ease compliance and support their HFCV compliance strategy.

While Ford and DaimlerChrysler continued selling NEVs, GM partnered with NEV companies to build 5.000 NEVs and give them away free, threatening to kill the business case of Ford and DaimlerChrysler and reaping large numbers of ZEV credits (Interviewee 10; O'Dell, 2002). At the same time, GM was "sponsoring a bill in the state Legislature … to restrict NEVs to streets with speed limits of 25 mph or less", which DaimlerChrysler noted "would effectively kill NEVs' usefulness" and was perceived by Sierra Club as "a GM strategy to mess with their competitors" (O'Dell, 2002, p.1). This example also illustrates how strong competition in new technologies extends to the political spheres.

Another example of a relation between compliance and political influence strategies, was the case of HEVs, which were promoted by Toyota and Honda—leaders in HEV technology—but opposed by GM and DaimlerChrysler. Toyota argued that hybrids would help transition to ZEVs, while GM and DaimlerChrysler countered that their environmental benefits and consumer demand were minimal (CARB, 2004, p.99). In their commissioned studies, AIR stressed that this category should be expanded to include advanced internal combustion engine vehicles and Sierra concluded that credits for HEVs were disproportionally high (CARB, 2004).

4.4.3 The 2008 rulemaking

Car manufacturers' political strategies became predominantly proactive in their focus, beginning in 2008 (see Table 4.3). Car manufacturers' increased support for the 2008 amendment reflects a trend towards a more compliance-oriented political strategy.

Defensive CPAs

During the 2008 rulemaking, car manufacturers' defensive political strategy focused on information tactics, specifically lobbying. They argued that the ZEV mandate constituted a premature, short-term and costly technology-forcing policy that would hamper long term commercialization (CARB, 2008). After the 2008 amendments were adopted by CARB, the car sector created a unified campaign through its industry trade associations AAM and Global Automakers, to use legal arguments to oppose EPA granting a waiver for the 2008 ZEV amendments.

Compliance and proactive CPAs

In the period leading up to the 2008 rulemaking, car manufacturers' compliance strategies started to further diverge, as PHEVs emerged as a technological alternative and HFCVs became a more frequently used alternative to EVs (see Table 4.3). We identified various instances in which car manufacturers' competitive proactive CPAs, including information tactics like lobbying and commissioning studies, show a strong relation to their compliance strategies. Firstly, to support their emerging HFCV compliance strategy, some car manufacturers continued to lobby for better HFCV provisions, contending that HFCV was the most promising ZEV technology, though still technologically immature (CARB, 2006). They argued that to foster technological development, only 30 vehicles per generation per company would need to be built; more would be a waste of resources with no gain in learning (Hermance, 2006; Ford, 2008; CARB, 2008). "So instead of producing 4,000 EVs, they wanted to produce 30 test HFCVs," (Interviewee 5) which is much cheaper. Using that argument, their lobby convinced CARB that no additional HFCVs were necessary to comply with the ZEV mandate adopted by ten other states (CARB, 2008), something that was vigorously opposed by NGOs (NRDC et al., 2008).

Secondly, car manufacturers investing in PHEVs also convinced CARB that much like HFCVs, PHEVs were technologically immature and should therefore also be perceived as test vehicles and therefore receive higher credits (CARB, 2008; Ford, 2008). Toyota successfully lobbied for credit for PHEVs with an all-electric-range of as little as 10 miles, arguing that consumers should be allowed to trade off battery costs against range (CARB, 2008, p. 102). Toyota subsequently developed and sold a Prius PHEV with 11 miles of electric range (Toyota, 2013).

GM, on the other hand, was unsuccessful in its lobbying to establish a new, higher-credit category of Extended Range EVs (EREV) for their Volt, not gaining support for their argument that such vehicles gave higher environmental benefits by overcoming EV range anxiety (GM, 2008).

Thirdly, because no EVs had been introduced since 2003 (CARB, 2013), EV proponents like Nissan successfully argued that EVs, like HFCVs, were also not yet market-ready and should therefore also be able to exploit the less stringent HFCV alternative compliance path, even if EVs received lower credits than HFCVs (Interviewee 6; CARB, 2008).

Fourth, Chrysler commissioned studies on NEV use to argue that because of their environmental benefit and their disproportionately low credits compared to PHEVs, NEV credits should be increased (Chrysler, 2008; GEM, 2005).

CARB caused a split in the car manufacturers' political coalition by granting "Intermediate Volume Manufacturers" (IVMs) a time extension to comply with the mandate's ZEV requirements. The "Large Volume Manufacturers" (LVMs) created an ad hoc lobbying coalition to successfully oppose this time extension, while IVMs, which were less well organized, lobbied in its favor (CARB, 2008; Interviewees 11; 12; 13). Because of this conflict, the AAM and Global Automakers were not involved in lobbying (Interviewees 7; 8).

4.4.4 The 2012 rulemaking

During the 2012 rulemaking car manufacturers' political strategies became even less defensive and more proactive and compliant, see Table 4.3.

Defensive CPAs

Defensive CPAs comprised the information tactic lobbying, which included only a few defensive comments coming predominantly from coalitions (see Tables 4.3 and 4.4). These coalitions' defensive comments focused on the mandate's infeasibility and inconsistency with other parts of the Advanced Clean Cars program. Additionally, car companies voiced their concerns about the rapid ramp up of mandated sales, especially related to required sales in the 10 states outside California beginning in 2018 (CARB, 2012a; Interviewees 6; 12).

In 2013, after issuance of the mandate, with initial sales of Nissan's EV Leaf and GM's PHEV Volt being slower than projected (Voelcker, 2013), many of the companies became increasingly concerned about the mandate. AAM and Global Automakers formed a closed industry front to oppose EPA's decision to waive federal pre-emption. They felt that neither the CARB nor EPA had fully considered the lack of infrastructure and consumer demand for the increasing standards, especially in the ZEV states outside California (GA and AAM, 2013). While the ad hoc coalition of LVMs voiced their collective opposition towards the ZEV mandate, the LVMs individually were more supportive. This underlines how car manufacturers use coalitions to continue opposing the mandate, while supporting it individually.

Compliance and proactive CPAs

In the period preceding the 2012 rulemaking, compliance strategies of car manufacturers focused predominantly on EVs and PHEVs, with increasing USA sales in 2011 (AFDC, 2013). Table 4.3 shows that NEV and HFCV production to comply with the ZEV mandate decreased during this period. The most important example of proactive competitive lobbying to support a compliance strategy is provided by BMW. BMW convinced CARB to establish a new, more highly credited BEVx category to accommodate their proposed EREV i3, with much the same arguments as GM used unsuccessfully in 2008 for their EREV Volt. They asked for additional credit for a vehicle that would have an optional limp-home motorcycle engine to reduce range anxiety (Turrentine et al., 2011; Interviewee 11). BMW argued, based on a study they commissioned that drivers would use their EV more if they had this limp-home capability (Ibid.). BMW was successful, where GM failed, because they posited a vehicle that more closely approximated a pure EV and because they provided more evidence (Interviewees 2; 11; 15). In an attempt to prevent its competitors from yielding a competitive advantage from the BEVx category, Ford opposed it by stressing that the credits are 'overly generous' and provided car manufacturers with an 'escape hatch' from producing pure-ZEVs (CARB, 2012a, p. 50-51).

Another example of car manufacturers trying to reinforce their compliance strategies through competitive proactive strategies is the over-compliance option. This over-compliance option resulted from negotiations between car makers and CARB regarding the California/national corporate average fuel economy and greenhouse gas regulations (CARB, 2012b; Interviewees 2; 6; 14). The intent was to gain support for these regulations from Honda and Hyundai in exchange for the over-compliance option, of which they were the most likely beneficiaries (Interviewees 2; 6). Because of diverging compliance strategies, industry was much divided over the over-compliance provision. The AAM opposed this provision, arguing that it would give a "significant competitive advantage" to car manufacturers with lower average fleet emissions – predominantly those who were not members of AAM (AAM, 2012, p.13). Not surprisingly, Global Automakers, which included Hyundai and Honda as its members, supported it (Interviewee 7).

Car manufacturers linked their general proactive lobby to their defensive lobby arguments, arguing that if the ZEV mandate were to ramp up fast with adoption by other states, that these states should provide more demand-pull and infrastructure support for ZEVs (Interviewees 8; 11; 12; 13). They argued that, like California, these states should adopt a "carrot and stick" approach and complement the ZEV mandate with regulations that provide financial, parking, carpool lane and infrastructure incentives for the technologies they were forcing onto the market. As of 2013, ZEV adopting states have increasingly adopted this "carrot and stick" approach by taking on ZEV supporting initiatives (ZEV workshop, 2013).

4.4.5 Longitudinal analysis of political strategies

We discuss the changes in car manufacturers' and their coalitions' political strategies and underlying actions toward the ZEV mandate in Subsections 4.5.1 and 4.5.2 respectively. Tables 4.3 and 4.4 provide an overview of these actions in response to the mandate's successive amendments and their waivers of federal preemption over the timeframe 2000-2013. Reflecting on the types of tactics used by car manufacturers and their coalitions to influence the ZEV mandate, we found that only information and litigation tactics were used. In contrast to the 1990s, no constituency tactics like grassroots mobilization or astroturfing were used by car manufacturers to influence the ZEV mandate during the period 2000-2013 (Interviewees 2; 10). Furthermore, interviewees indicate that political connectedness and financial tactics were not pursued by industry to influence the ZEV mandate, because of CARB's autonomous structure, and because strong legal and political support for its ZEV mandate render such tactics ineffective. Also, state laws discourage the use of financial tactics such as paying travel expenses and honoraria to board members (Interviewees 2; 15; Collantes and Sperling, 2008).

Table 4.3, Overview of car manufacturers' actions in response to the ZEV mandate and associated waivers of federal preemption

	2001 Amendments	2003 Amendments	2008 Amendments	2012 Amendments
Defensive actions:	Lobbying: 349 comments; made EV demand seem smaller; proposed alternative programs; commissioned studies attacking the mandate; expert testimonies; delayed the regulatory process with multiple requests for data	Lobbying: 87 comments; litigated the ZEV mandate; expert testimonies attacking the mandate; proposed alternative programs; commissioned studies attacking the mandate; delayed the regulatory process with multiple requests for data; (distraction)	Lobbying: 51 comments	Lobbying: 7 comments
General proactive actions:	Lobbying: 34 general; commissioned studies for better provisions	Lobbying: 20 general; commissioned studies for better provisions	Lobbying: 34 general; commissioned studies for better provisions	Lobbying: 28 general; commissioned studies for better provisions
Competitive proactive actions:	Lobbying: 70 competitive comments; commissioned studies for better provisions	Lobbying: 54 competitive comments; commissioned studies for better provisions	Lobbying: 81 competitive comments; commissioned studies for better provisions	Lobbying: 53 competitive comments; commissioned studies for better provisions
Compliance actions:	No statements of support; <20 HFCVs; 2410 EVs; 1.000-26.000 NEVs	6 statements of support on provisions; 20-40 HFCVs; 600 EVs; 1.000-26.000 NEVs	77 statements of support on provisions; 270 HFCVs; ~260 EVs; ~3.000 NEVs	63 statements of support on provisions; 190 HFCVs; ~12.110 EVs; <1.000 NEVs

Table 4.4, Overview of car-manufacturers-coalitions' actions in response to the ZEV mandate and associated waivers of federal preemption

	2001 Amendments	2003 Amendments	2008 Amendments	2012 Amendments
Defensive actions	Lobbying: 26 defensive comments; commissioned studies attacking the mandate	Lobbying: 24 defensive comments; commissioned studies attacking the mandate	Lobbying: 16 defensive comments	Lobbying: 53 defensive comments
General proactive actions	Lobbying: 9 proactive comments; commissioned studies attacking the mandate	Lobbying: 1 proactive comment; commissioned studies attacking the mandate	Lobbying: 10 proactive comments	Lobbying: 9 proactive comments
Competitive proactive actions	Lobbying: 8 proactive comments; commissioned studies attacking the mandate	None	Lobbying: 7 proactive comments	Lobbying: 7 proactive comments
Compliance actions:	None	None	None	None

Longitudinal analysis of car manufacturers' political strategies

Table 4.3 shows that over time, car manufacturers' defensive CPAs became less frequent and less diverse: what started with a plethora of CPAs, like commissioning studies, undermining the regulatory process in various ways, litigation and extensive lobbying, was eventually reduced to an occasional defensive comment. At the same time, the share of proactive CPAs including lobbying and commissioning studies increased. As indicated in the previous sections, competitive proactive CPAs were often used to support the compliance strategies of car manufacturers that diverged and changed over time from NEVs and EVs in the early 2000s, to HFCVs in the mid-2000s, to PHEVs and EVs beginning in the late 2000s (AFDC, 2013).

To study the most frequently used CPA, lobbying, we collected 1140 comments made by car manufacturers and their coalitions throughout the study period. Figure 4.1 displays the 970 comments made by individual car manufacturers with regard to the four amendments and their waivers of federal preemption.

These comments have been categorized into the political strategies we identified in Section 2, i.e. compliant comments of support for the mandate and its provisions, competitive proactive comments, general proactive comments and defensive comments. The figure shows a clear trend from strong defensive lobbying in the early 2000s, towards increasingly proactive and compliant comments, as well as a trend from frequent lobbying to less frequent. These trends were recognized by the interviewees. Even though the 2012 amendments were the first to increase instead of relax the ZEV mandate (Interviewees 2; 3; 6; CARB, 2012a), defensive lobbying reduced even during this period.

This trend in lobbying depicted in Figure 4.1 and the trend in CPAs more generally depicted in Table 4.3, confirms Hypothesis 1: Throughout the timeframe 2000-2013, car manufacturers became less defensive and more proactive in their political strategies towards the ZEV mandate. We thus find a shift in strategy from protecting the status quo towards trying to gain competitive advantage by reducing compliance costs for specific technologies.

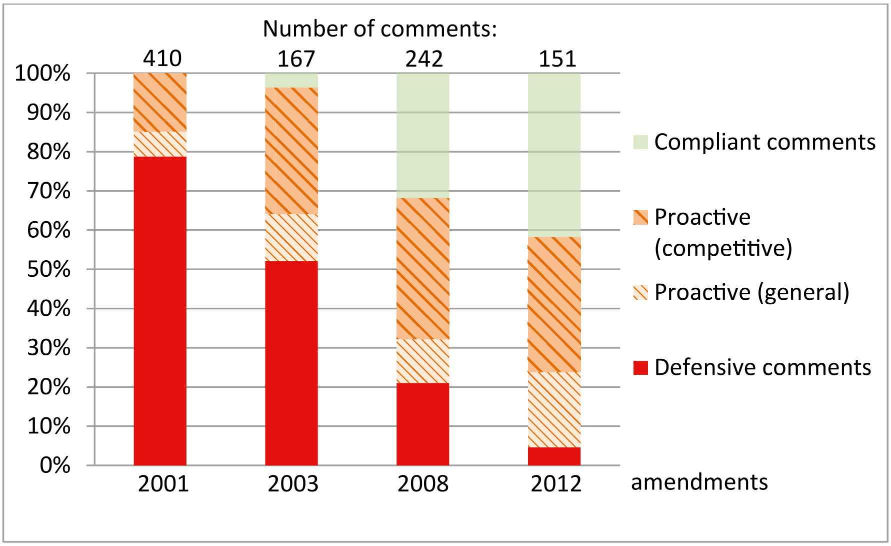


Figure 4.1, Changes in car manufacturers' political strategies based on their comments on ZEV amendments, reviews and waiver grants

Longitudinal analysis of coalitions' political strategies

Table 4.4 shows the political orientation of the actions undertaken by car manufacturers' political coalitions in response to the ZEV mandate over the timeframe 2000-2013. These coalitions included industry associations and ad hoc lobbying coalitions. The table shows that primarily to oppose the ZEV mandate, coalitions used lobbying and, in the early 2000s, also commissioned studies. Based on the same principles of Figure 4.1, Figure 4.2 shows more insight into the dynamics of lobbying by coalitions. Below the bar chart, Figure 4.2 also shows which coalitions affected the various amendments and respective waivers of preemption. The figure shows that there is no trend observable away from defensive towards proactive lobbying. Also, coalitions have never voiced support of the mandate. This finding confirms Hypothesis 2: Throughout the timeframe 2000-2013, industry associations and lobby coalitions continued to be more defensive in their political strategy than their member car manufacturers by opposing the ZEV mandate more strongly.

The previous is in line with what CPA literature suggests and what interviewees confirm, that coalitions are primarily used for the defensive "dirty work" because of the politically sensitive nature of the lobbying (Interviewees 2; 3; 6; 7; 16). The industry associations' main job was to combine forces in preventing the EPA from granting a waiver for the ZEV mandate (Interviewee 6), which required the coalitions' legal instead of the car manufacturers' technical expertise (Interviewees 7; 16). Interestingly, the AAM was not involved in the lawsuits against the mandate because not all AAM members agreed on this approach (Interviewees 12; 13). The ad hoc lobbying coalition of large volume manufacturers was formed to better protect their interests when manufacturer size became a more prominent issue in the 2008 rulemaking (Interviewees 7; 8; 12).

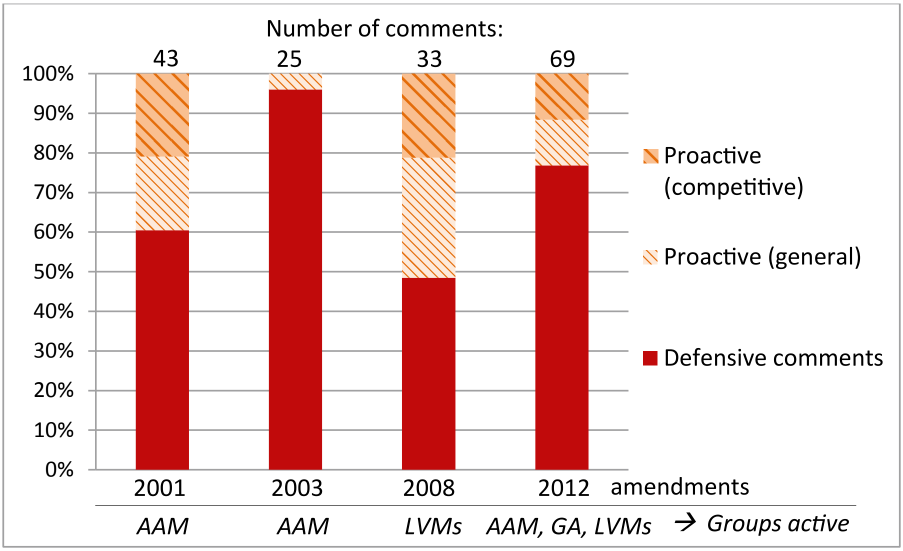


Figure 4.2, Changes in political strategies of car manufacturers' coalitions, based on their comments on ZEV amendments, reviews and waiver grants, and an indication of who were lobbying when

4.5 Conclusions and discussion

This research has shed light on the political strategies and underlying CPAs of car manufacturers and their coalitions toward the ZEV mandate over the period 2000-2013. In this case study we found support for hypothesis 1 that "Throughout the timeframe 2000-2013, car manufacturers have become less defensive and more proactive in their political strategies towards the ZEV mandate". The results indicated that car manufacturers changed their political strategy to support their changing compliance strategy. We also found evidence to support our second hypothesis—that "Throughout the timeframe 2000-2013, industry associations and lobby coalitions continued to be more defensive in their political strategy than their member car manufacturers by opposing the ZEV mandate more strongly" because members use these coalitions to oppose sensitive interventionist policies.

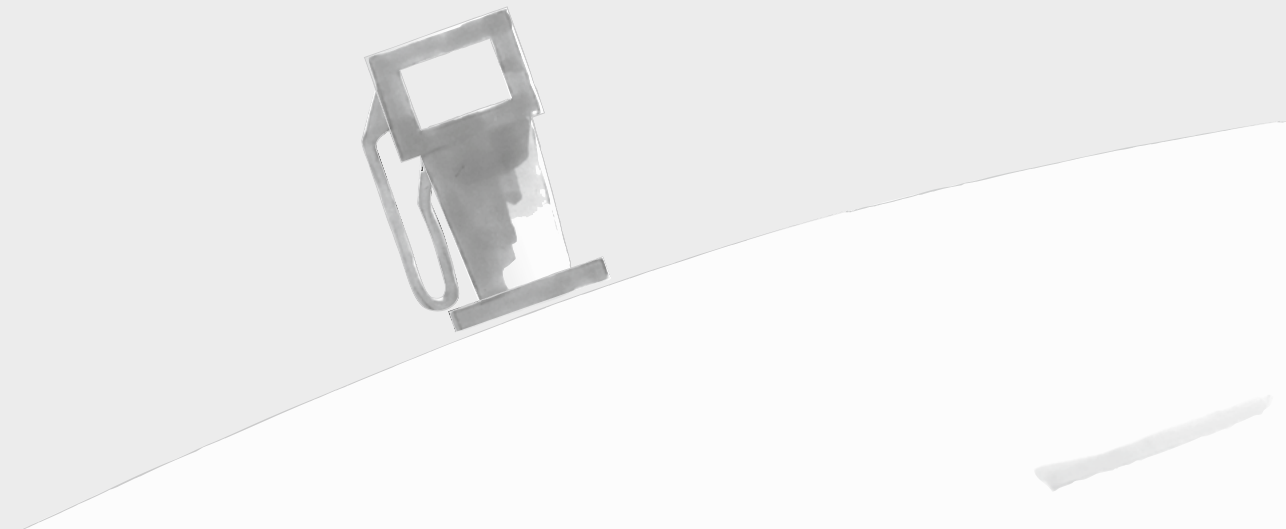
This longitudinal case study adds to CPA literature by showing how firms can change their political strategy over time and that firms combine multiple political strategies at the same time. We documented how car manufacturers' compliance strategies diverged increasingly over time as new low and zero emission vehicle technologies emerged. To support these diverging compliance strategies, car manufacturers changed their political strategy from defensive to proactive – trying to create favorable conditions for the low and zero emission vehicle technologies they were investing in. To gain a competitive advantage over their rivals under the ZEV mandate, they lobbied for mandate provisions favorable to the vehicle technologies they championed, while opposing provisions that were beneficial to the vehicle technologies of their competitors. This competition in proactive political strategies based on the diverging interests of car manufacturers, helped break apart the previously closed industry front of opposition to the mandate. This chapter thus provides insights into how competition in compliance and political influence strategies helped break down defensive industry fronts and facilitate a transition towards low and zero emission vehicles.

It should be noted that car manufacturers like GM and Chrysler were hit hard by the recent economic crisis and received governmental support, while other such as Nissan receive large subsidies to develop sustainable technologies. These contextual factors are likely to have influenced both their compliance (affecting what technologies to invest in) and political influence strategies (firms receiving governmental support have less legitimacy to oppose regulation) on the ZEV mandate.

To determine to what extend our case study findings are generalizable, we recommend further research to focus on other instances in which competitive forces may drive apart the industry front of opposition towards policy interventions. Validating this process in for different regulations and in other sectors may provide a better understanding of the role of competition in facilitating implementation of policy interventions. Such understanding may be used by policymakers to affect firms' political strategies, allowing governments to implement policy with less defensive interference by firms. Additionally, car manufacturers may adopt different political strategies for the various regulations they face at different spatial scales. Future research may study to what extend car manufacturers adopt similar political strategies to this wide array of regulations. We also recommend to further study the role of (global) innovation strategies in breaking apart the industry front and causing changes in political influence strategies. Such a study requires extensive data collection on the development and implementation of technologies firms are investing in to comply with the technology-forcing regulation.

4.5.1 Policy recommendations

We provide three recommendations for policymakers to reduce industry opposition to their regulations. Given our finding that lobbying coalitions and industry associations are, and over time continue to be, more defensive in their political strategies than individual firms, we suggest that policymakers interact more with individual firms to gain industry support for their regulations. Given a second finding that strong technological competition between car manufacturers drove a wedge between the companies, resulting in competitive proactive CPAs that broke apart the defensive industry front, we recommend that policymakers negotiate preferential treatments of certain technologies over others (i.e. being responsive to their competitive proactive CPAs). In that way, firms can be made to support the regulation if they believe they can gain competitive advantage over their competitors. Thirdly, we highlight the political effectiveness of employing a "carrot and stick" approach that combines technology-forcing with demand-pull policy to diffuse industry opposition. Demand-pull policies, such as financial incentives, create demand for new technologies, encouraging firms to reduce their opposition to the technology-forcing policy.



5 Corporate responses to technology-forcing regulations: innovation and political influence strategies by car manufacturers

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 recently developed conceptual framework 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 firstly, car manufacturers use specific combinations of innovation and political influence strategies, depending on their value maintaining or value creating nature. Secondly, manufacturers change their strategies and become more value creating over time, which supports socio-technical transition processes. Thirdly, we refine contemporary strategy typology by identifying subclasses in defensive (opposition and slowdown) and proactive strategies (shaping, support and progressive).

This chapter has been submitted for publication at Environmental Innovation and Societal Transitions by J.H. Wesseling, J.C.M. Farla and M.P. Hekkert.

5.1 Introduction

Our society faces many sustainability problems and a transition towards a more sustainable society is imperative (EC, 2012; UN, 1987; Van den Bergh et al., 2011). Such a transition will involve the development of novel technologies, besides many changes in the socio-economic and institutional contexts that are necessary to incorporate 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; ; 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 policy is frequently used to trigger or even force firms to engage in innovations that contribute to the transition to a more sustainable society. Examples of such policies include tax incentives, standards, 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; Chandy and Tellis, 2000; Wesseling et al., 2014b). Without 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).

When firms are confronted with regulatory pressure to innovate, they will not simply comply by engaging in the mandated innovation, but 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, in order to maintain their existing profitable position. With their unwillingness to innovate and potential influence on policy interventions, powerful incumbents may pose a significant barrier to socio-technical transition.

However, the ability of firms to influence regulations has largely been overlooked in the innovation 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).

Yet recently, Oliver and Holzinger (2008) have developed a general conceptual framework in which they link firms' compliance and active political influence strategies. They distinguish between value maintaining and value creating strategies. Value maintaining strategies involve efficiently adapting the firm's resources and capabilities to regulatory changes (compliance), or to oppose regulations that threaten the status quo (influence). Value creating strategies on the other hand involve exploiting first mover advantages through internal adaptation to anticipated regulatory changes (compliance) and by actively shaping regulations to the firm's advantage (influence).

Applying Oliver and Holzinger's (2008) framework to technology-forcing regulations implies that their concept of 'compliance strategy' relates strongly to that of 'innovation strategy', as compliance requires innovation in such cases. Oliver and Holzinger (2008, p. 515) recommend further research employ this framework to research the "breadth of a firm's strategic repertoire" and identify possible "synergies" in combinations of types of strategies. Accordingly, we study if and how incumbents combined innovation strategies and political influence strategies in response to technology-forcing regulation. By doing so, we provide insights into the role incumbents played in the socio-technical transition to a more sustainable society.

In this study, we focus on the car industry, as passenger cars emit 12% of the EU's total CO_2 emissions (EC, 2007). More specifically, the case we study is 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 Oliver and Holzinger's (2008) relatively static 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, 2012). 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 chapter is structured as follows. Section 2 discusses Oliver and Holzinger's conceptual framework on corporate response strategies to regulatory change and links it to innovation strategy literature. The Methods are discussed next, followed by a brief description of the ZEV mandate in Section 4, and the Analysis in Section 5. We conclude by summarizing the findings of this chapter and by reflecting on how the field of transition studies may benefit from studies that combine firm-level innovation strategies and political influence strategies.

5.2 Theoretical background

5.2.1 Corporate political activity

The Corporate Political Activities (CPA) literature argues that in strongly regulated environments, firms may strengthen their competitive advantage by engaging in political strategies (Hillman and Hitt, 1999; Oliver and Holzinger, 2008). 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).

Embedded within the CPA literature, Oliver and Holzinger (2008) developed a comprehensive conceptual framework on corporate response strategies to regulatory change. We adopt this framework because it allows us to study how firms combine innovation and political influence strategies in an integrated way. The framework distinguishes between compliance and influence, and between value maintenance and value creation, see Table 5.1. Oliver and Holzinger (2008, p. 505) define political compliance strategies as firm-level actions undertaken in conformity with political requirements and expectations for the purpose of maintaining or creating value, by adapting to or anticipating public policy. Political influence strategies comprise a timed sequence of consistent CPAs to influence public policy in a particular way. We refer to value maintenance as "the preservation of those firm assets and competences that constitute the foundation of firm rents", and to value creation as "the invention or reconfiguration of firm assets or competences that constitute an original or unique addition to firm rents" (Oliver and Holzinger, 2008, p. 497).

Table 5.1: Corporate response strategies to regulatory change (Oliver and Holzinger, 2008)

		Value perspective	
		Value maintenance	**Value creation**
Strategic orientation	Compliance	**Reactive strategy** *Efficiently align internal resources and capabilities with regulatory change*	**Anticipatory strategy** *Exploit early-mover advantages of aligning with anticipated regulatory change*
	Political influence	**Defensive strategy** *Engage in political influence to oppose regulatory change and retain the status quo*	**Proactive strategy** *Engage in political influence to shape regulatory change to gain competitive advantage*

Compliance strategies focus on shaping the firm's internal resources to comply with existing or anticipated regulations. Firms employing a reactive strategy aim to maintain the value of their resources and competences by aligning them efficiently and effectively with regulatory demands (Carroll, 1979; Buysse and Verbeke, 2003; Oliver and Holzinger, 2008). For example, firms installing cheap but effective emission abatement hardware to comply with emission standards, adopt a reactive strategy. Firms with an anticipatory strategy anticipate regulatory changes to create value by exploiting early-mover advantages in adopting innovative operational routines to comply with anticipated regulatory demands (Ibid.). To illustrate, battery manufacturers Toshiba and Hitachi anticipated more stringent battery regulations and therefore quickly acquired and implemented acid-free and renewable battery technology, which reduced their compliance cost when the more stringent regulations were issued (Shrivastava, 1995; Oliver and Holzinger, 2008).

Political influence strategies utilize CPAs to influence regulation. Firms engage in value maintaining defensive strategies to oppose regulations that threaten the value of their assets and to protect the favorable status quo (Shaffer and Hillman, 2000; Oliver and Holzinger, 2008; Stenzel and Frenzel, 2008; Hillman et al., 2004; Carroll, 1979). Tobacco companies for example, are famous for their defensive strategies, trying to thwart restrictive regulations on tobacco. Proactive 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 firms may increase their success in obtaining government subsidies or winning government tenders, or they may attempt to shape regulations in ways that involves low compliance cost for the firm itself, but disproportionately raises compliance costs for competitors (Oliver and Holzinger, 2008).

5.2.2 Technology-forcing regulation: compliance through innovation strategies

Applying Oliver and Holzinger's (2008) conceptual framework on corporate political strategies specifically to technology-forcing regulations implies that to comply, firms need to adopt innovation strategies. In such instances, compliance strategies have to relate to 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 develop technology and sustain technology lead-times (Freeman and Soete, 1997). Commercialization involves mass marketing of the technology and requires significant investments in production facilities and marketing. Strategic management literature generally distinguishes three innovation strategies: a first mover strategy, a quick follower strategy or a laggard strategy (Lieberman and Montgomery, 1998; 1988; Freeman and Soete, 1997; Robinson and Chiang, 2002). In relation to the terminology of Oliver and Holzinger (2008), we postulate that 'anticipatory innovation strategies' include 'first movers' that invest heavily in R&D to maintain technology-lead time and pioneer in commercialization, and 'quick followers' that also invest heavily in R&D, enabling them to quickly follow first movers to the market (Lieberman and Montgomery, 1998). We relate 'reactive innovation strategies' to 'laggards', which lack innovative capabilities and minimize costs by investing little in R&D and entering the market last (Lieberman and Montgomery, 1998).

In some instances technology-forcing regulations fail 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 instead may pursue compliance strategies that constitute a low cost alternative that they perceive as preferential to non-compliance, and which possibly involves the exploitation of regulatory loopholes (Ford, 2008; Anderson and Sallee, 2011). We also group such compliance strategies that entail the limited introduction of new technologies under 'reactive 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 technology specific (Teece et al., 1997) and differ per type of innovation. Innovations may be typified according to the technological (incremental/radical or competence-destroying) and the socio-economic (modular – 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).

5.2.3 Interrelation between innovation and political influence strategies

Table 5.2 displays our adaptation of Oliver and Holzinger's (2008) conceptual framework when applied to the case of technology-forcing regulations. The table distinguishes two dimensions; the upper quadrants are distinguished in the extent of innovation (reactive vs. anticipatory) and lower quadrants in the nature of political influence (defensive vs. proactive). Oliver and Holzinger (2008) suggest that firms may exploit synergies in combining different strategies, something we will explore in the Analysis section.

Table 5.2: Response strategies to technology-forcing regulation, comprising innovation and political influence strategies, adapted from Oliver and Holzinger (2008)

		Value perspective	
		Value maintenance	**Value creation**
Strategic orientation	Innovation (compliance)	**Reactive innovation strategy** *Cost-efficiently comply with technology-forcing regulation through laggard innovation strategies.*	**Anticipatory innovation strategy** *Anticipate increasing technology-forcing standards and stay ahead of regulatory change through first mover and quick follower innovation strategies.*
	Political influence	**Defensive strategy** *Engage in political influence to oppose regulatory change.*	**Proactive strategy** *Engage in political influence to shape regulatory change to gain competitive advantage.*

5.3 Methods

5.3.1 Case study design

To study how firms respond through innovation and political influence strategies to technology-forcing regulation, we conduct a longitudinal case study of the innovation and political 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 5.3 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 are technology-specific 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), full-electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs). Ranging from competence-enhancing to competence-destroying, these technologies are listed and described in Table 5.4.

Table 5.3, Indicators of R&D, commercialization and political influence activities

Concept:	**Indicator:**	**Database (per technology and firm):**
R&D	Patents	Global Patent Index program from European Patent Office.
Commercialization	Sales; CO_2 emissions	US (and EU) production/sales figures for alternative vehicle technologies; CO_2 emissions for ICEV technology
Corporate Political Activities	Arguments, litigation, compliance	ZEV mandate database: public hearing transcripts, public documents, letters to CARB and EPA, interviews, complementary sources

Our study focuses on the six ‘large volume’ car manufacturers that 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 manufacturers are General Motors, Chrysler, Ford, Toyota, Honda and Nissan. Although the analysis centered on these six firms, merger and alliance partners like DaimlerChrysler (1998-2007), Fiat-Chrysler (2014-now) and Renault-Nissan (1999-now) were also taken into account as contextual factors in the analysis.

Table 5.4: Acronyms and descriptions of the sustainable automotive technologies included in this study, ranging from competence-enhancing (top) to competence-destroying (bottom).

↓ Increasing competence-destruction	Technology	Description
	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	Neighbourhood electric vehicles are low speed, low performance EVs that are essentially glorified golf carts that require recharging infrastructure but can easily utilize home charging.
	EV	Full-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 refuelling infrastructure.

5.3.2 Operationalization of R&D

To measure the research and development activities of each technology, we used patent data, since patents are a good indicator for R&D activities (Archibugi and Pianta, 1996). Patent 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 used in Chapter 2. For the PHEV query's basis we combined 'hybrid' with 'plug-in' and 'range-exten*', and the NEV query's basis comprised 'neighboorhood 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 patents 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. We used a publication level filter to ensure relevant patent applications and ordered the data on the 'date of filing' to reduce the time lag between invention and application for the patent. To prevent overlap in patents between technologies, we added mutually exclusive search strings to the basic search queries. For a more elaborate discussion on the search query formation, see Chapter 2. Obtained patents were checked for relevance.

5.3.3 Operationalization of commercialization

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 (OECD and 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 large fuel economy differences between cars. Instead we used Corporate Average Fuel Economy (CAFE) data of each manufacturer's car fleet, which we controlled for the weight conform EPA and Ricardo measures (EPA, 2014a; Blanco, 2009) to remove weight-induced fuel efficiency bias. These data were obtained from the EPA (EPA, 2013).

5.3.4 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 Chapter 4.

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.

5.4 The ZEV mandate in the period 1990-2013

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 and allowed PHEVs to comply with part of the ZEV requirements (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.

5.5 Analysis

5.5.1 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 Figures 5.2-5.5 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 the ICEV technology in Figure 5.1. 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). 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 Analysis Section. Table 5.5 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 5.5 but is incorporated in the following subsections.

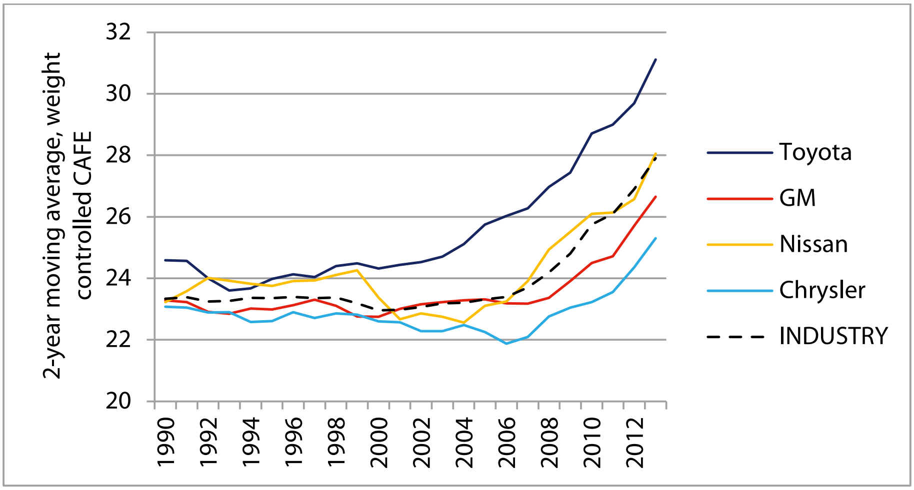


Figure 5.1, 2-years moving average, weight controlled CAFE of General Motors, Chrysler, Toyota and Nissan, over the period 1990-2013 (Source: EPA, 2014b).

Table 5.5, 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%

5.5.2 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 EV strategy and would produce no more than 842 compliance EVs and used their 'inability' to sell more as an argument to oppose the mandate (Boschert, 2006). Figure 5.2 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 Figure 5.1. 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 compensate for its reactive innovation strategy.

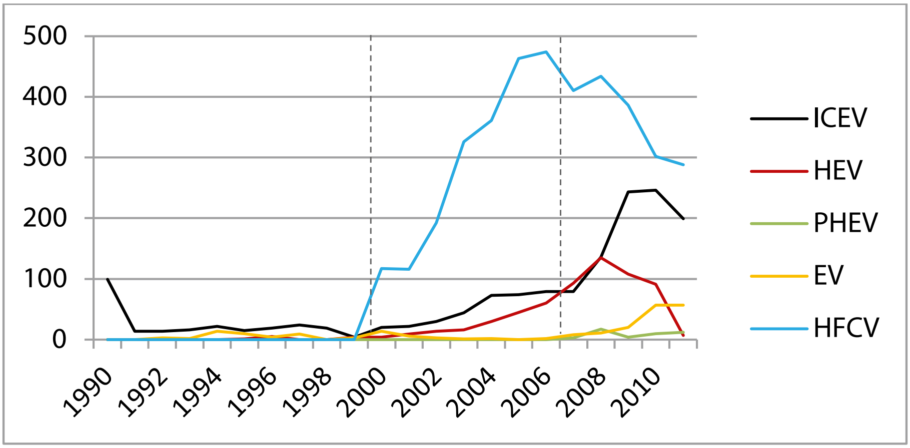


Figure 5.2, General Motors' patent applications over 1990-2012

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 Figure 5.1, nor did they sell any low emission vehicles (Marklines, 2014). As indicated by Table 5.5, 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 slow to follow. In sum, during period 2 GM combined a mainly opposition-oriented political influence strategy to protect its vested interests, with a reactive innovation strategy to prevent non-compliance penalties.

GM became more innovative during period 3, increasing its sustainable R&D explosively and moving first in commercialization of PHEVs, having sold over 70.000 units worldwide between 2011 and January 2014 (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 (Figure 5.1). 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 5.5 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 now more anticipatory innovation strategies.

5.5.3 Innovation and political influence by Chrysler

Figure 5.3 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 Figure 5.1. 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 reactive innovation strategy that focused only on short-term compliance to prevented non-compliance penalties.

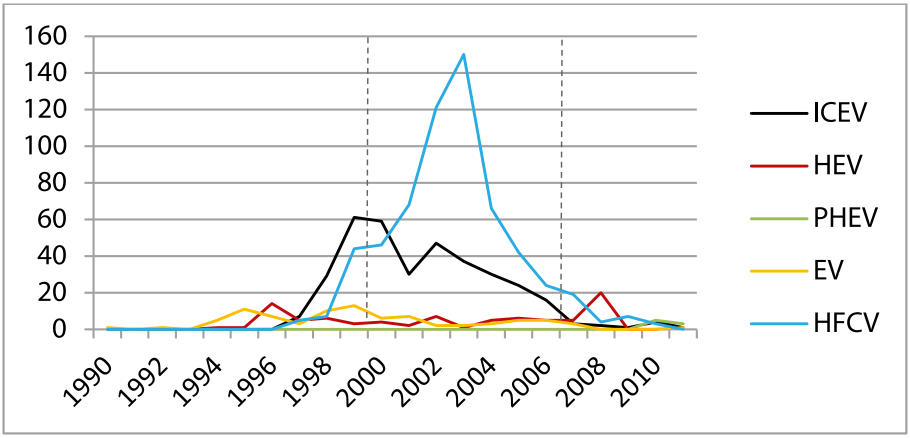


Figure 5.3, Chrysler's patent applications over 1990-2012

During period 2, Chrysler's R&D peaked, focusing mainly on HFCVs and clean ICEVs, see Figure 5.3. Chrysler's weight-controlled CAFE started lagging further behind on the industry average (Figure 5.1) 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 5.5, 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 (CARB, 2001; 2004). Chrysler 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 cheap reactive innovation strategy to prevent non-compliance penalties.

Chrysler's clean vehicle R&D dropped drastically during period 3, see Figure 5.3, and Chrysler's CAFE continued to fall farther behind on its competitors' (Figure 5.1). 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, 2012). 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, 2012). Hence, throughout the timeframe 1990-2013, Chrysler's political influence strategy has focused increasingly on shaping the mandate to support their still reactive innovation strategy.

5.5.4 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. As a result of Toyota's mainly clean-ICEV-oriented R&D strategy, Toyota had a fairly fuel efficient vehicle fleet, see Figure 5.1. As a compliance strategy, Toyota marketed 320 RAV4 EVs and would not meet the reportedly higher demand (Hoogma, 2000, p. 267). Toyota 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, Toyota lobbied defensively against the ZEV mandate during period 1 (Hoogma, 2000, p. 266; Collantes, 2006). Toyota thus combined a reactive EV innovation strategy and anticipatory 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 Figure 5.4. 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 (Figure 5.1). 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 Table 5.5. 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 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 the shaping CPAs oriented at supporting these innovation strategies, but otherwise Toyota's political influence strategy remains predominantly defensive.

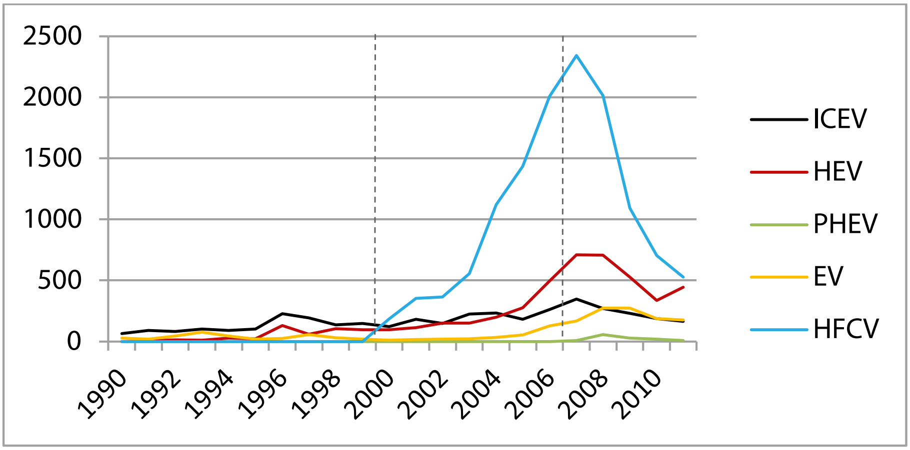


Figure 5.4, Toyota's patent applications over 1990-2012

Toyota's R&D efforts peaked in 2007-2008, see Figure 5.4, 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 (Figure 5.1). 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 5.5. Toyota tried to shape the mandate by lobbying in support of its quick follower PHEV strategy and its HFCV R&D and compliance strategy. In sum, Toyota's trend of increasing innovativeness coincides with a trend away from a defensive and towards a proactive, mainly supportive, political influence strategy.

5.5.5 Innovation and political influence of Nissan

Figure 5.5 shows that during period 1, Nissan was already doing quite some R&D in clean ICEV, EV and, as of 1997, also HEV technology. Nissan also had an above average CAFE, see Figure 5.1. To comply with the memorandum of agreement, they marketed approximately 210 compliance EVs in 1998 (Nissan, 2009; PIA, 2006). Already investing 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 reactive innovation strategies with a mildly defensive political influence strategy during the first period.

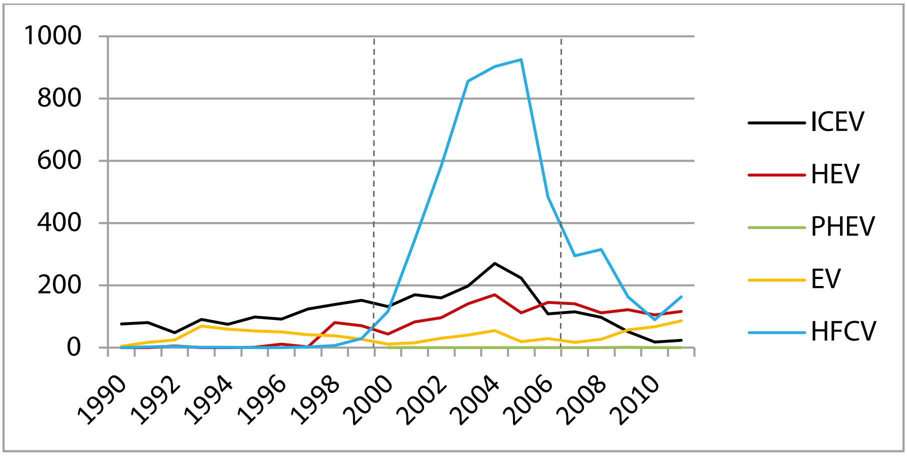


Figure 5.5, Nissan's patent applications over 1990-2012 (excluding Renault's patents)

During period 2, Nissan further increased its R&D in clean ICEV, HEV and particularly HFCV technology, at the costs of EV technology – see Figure 5.5. Nissan's CAFE actually dropped significantly during this time to below the industry average (Figure 5.1). Not having moved into mass commercialization yet, Nissan complied with the mandate through re-lease of EVs and testing of HFCVs (Nissan, 2002). Table 5.5 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.

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 anticipatory 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 5.5. Throughout the timeframe 1990-2013 Nissan became increasingly innovative and its initially defensive political influence strategy became strongly oriented towards support for the mandate.

5.5.6 Reflecting on the conceptual framework

Sections 5.2-5.5 show that car manufacturers indeed use different strategies at the same time. Figure 5.6 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 reactive innovation and defensive political influence strategies and adopted steadily more anticipatory 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 compliance and political influence strategies of either value maintenance (reactive and defensive) nature or value creation (anticipatory 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 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.

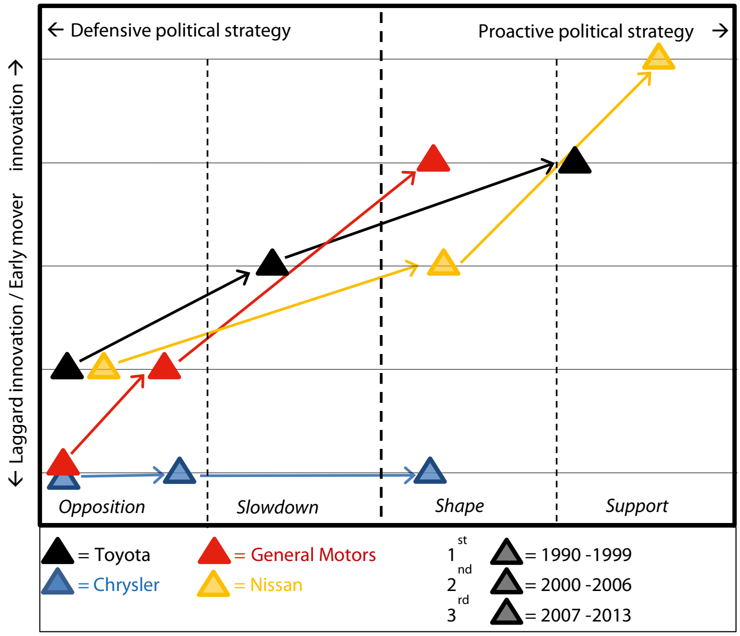


Figure 5.6, Changes in the innovation and political influence strategies of the car manufacturers over the periods 1990s, 2000-2006 and 2007-2013.

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 find that the least innovative firms use '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, reactive innovation strategies also support 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 technologies.

More innovative firms already betting on certain technologies to comply with the regulation tend 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 anticipatory 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 reactive innovation strategies. Chrysler for example lobbied to maintain the NEV credit category.

Still more innovative firms that have no trouble complying with the regulatory change 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 . During the 2012 ZEV amendments, Nissan for example supported the mandate as a whole.

5.6 Conclusion and discussion

To conclude, we have successfully applied the conceptual framework of Oliver and Holzinger (2008) on corporate response strategies to regulatory change, onto a case of technology-forcing regulation where compliance strategies become intertwined with innovation strategies. This case study complements Oliver and Holzinger's (2008) research in various ways. First, we find that firms combine innovation and political influence strategies. They combine value maintaining or value creating innovation and political influence strategies. In other words, where Oliver and Holzinger (2008) positioned the four strategy quadrants of their framework to be independent, we find that particularly the upper and lower quadrants are frequently combined. These combinations constitute the strategic synergies that Oliver and Holzinger (2008) suggested may exist. Second, we find that firms changed their strategies over time, generally from value maintenance strategies to value creation 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.

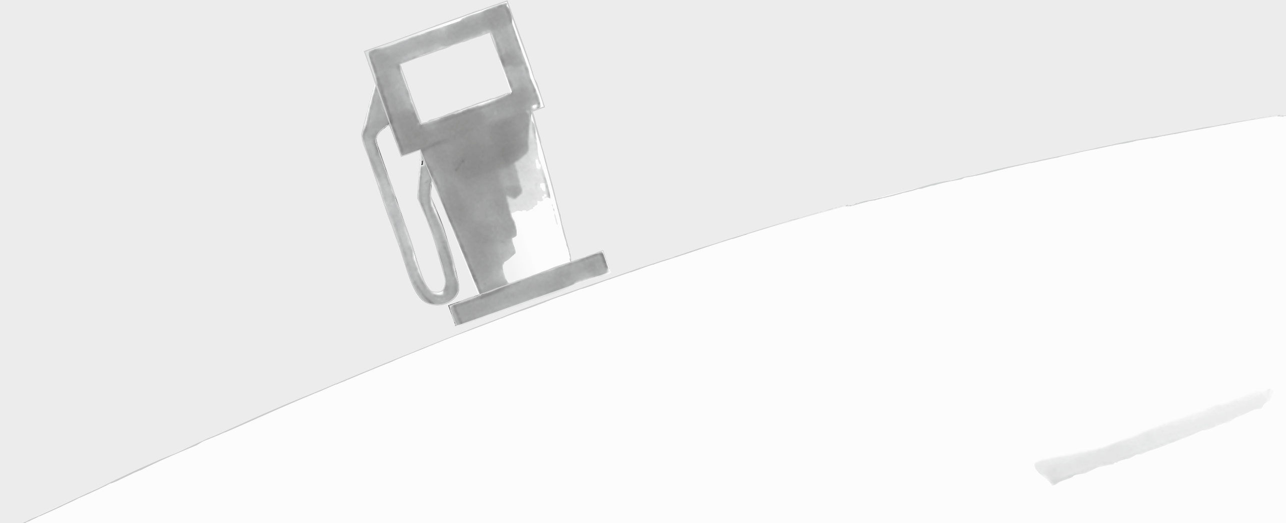
In reflection, ranging from value maintenance to value creation it would be possible to identify an even more extreme value creating subclass of proactive political influence strategies, namely not just supporting but progressing the stringency of the regulation. Looking outside the scope of our firm 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. Based on this case study Table 5.6 summarizes the framework of potential corporate response strategies to technology-forcing regulations.

By studying the interplay between and changes in innovation strategies and political influence strategies this study provides useful insights into the role of powerful incumbents facing socio-technical transition that is supported by technology-forcing policy interventions. We found that incumbent car manufactures could significantly slow down the transition to a sustainable mobility system by opposing technology-forcing regulation and limiting innovation to cheap compliance options. However, over time these incumbents invested in different, maturing clean vehicle technologies. To support these diverging innovation strategies, their political influence strategies became more proactive and oriented at supporting and shaping the mandate to the benefit of their individual, technology-specific innovation strategies. This supported the transition to a more sustainable mobility system, as more clean automotive technologies were brought to the market and, without the industry's opposition, policy makers could develop more stringent regulations.

Table 5.6: Response strategies to technology-forcing regulation identified in this case study

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="5">Value perspective</td></tr>
<tr><td colspan="2">Value maintenance</td><td colspan="3">Value creation</td></tr>
<tr><td rowspan="3">Strategic orientation</td><td>Innovation (compliance)</td><td colspan="2">Reactive innovation strategy
Cost-efficiently comply with technology-forcing regulation through laggard innovation strategies.</td><td colspan="3">Anticipatory innovation strategy
Anticipate increasing technology-forcing standards and stay ahead of regulatory change through first mover and quick follower innovation strategies.</td></tr>
<tr><td rowspan="2">Political influence</td><td colspan="2">Defensive strategies:</td><td colspan="3">Proactive strategies:</td></tr>
<tr><td>Opposition
Oppose regulation to protect incumbent technology</td><td>Slowdown
Slowdown and/ or relax regulation for innovation strategy to 'catch up'</td><td>Shaping
Shape regulation in favor of innovation strategy</td><td>Support
Support the regulation because rivals have higher compliance costs</td><td>Progressive
Increase stringency of regulation to increase rivals' compliance costs</td></tr>
</table>

Policy makers may thus expect initial opposition to technology-forcing regulations. However, as innovation processes get time to develop, technological competition becomes stronger, which results in reduced opposition. This, in turn, creates room for policy makers to ramp up their regulations. Since these findings are based on only one case, a fruitful area of further research would be to test whether the relation we found between innovation and political influence strategies is generalizable to other technology-forcing regulations aiming to drive socio-technical transitions.



6 Conclusions and discussion

6.1 Conclusions

In this section we will answer the research questions addressed in Chapters 2 through 5, before turning to the main research question of this dissertation.

6.1.1 Waves of technological development

Chapter 2 focused on the research question: **How did the forces of rivalry, dispersion and the presence of new entrants affect the duration of earlier waves of CVT development and how do these competitive forces affect the chances of continuation of the current wave of EV development?** Based on a longitudinal patent analysis, four waves of CVT development were identified over the period 1990–2010. Two of these waves, those of EV development (1990-1994) and HFCV development (1998-2007), were broken before becoming a commercial success. The wave of HEV development, starting in 1996 was continued and became a commercial success. The fourth wave is the current wave of EV development. Although the effect of the presence of new entrants could not be tested for all waves of development, our findings suggest that the combination of rivalry and dispersion positively relates to waves of continued technological development. We did find that new entrants accounted for most of the patent increases during the current wave of EV development. Based on these findings, it can be concluded that current EV developments are driven by rivalry and an increasing number of organizations, including new entrants. It is expected that through competitive pressures these organizations continuously trigger each other to invest more in the technological development of EVs, which will sustain this wave of EV development on the longer term. This study also found that incumbent car manufacturers dominated HEV and HFCV development, but that a wide array of different firms explored EV development. Such wide dispersion of EV development has an entry barrier lowering effect which may explain the large number of new entrants.

This chapter contributes to the literature by providing a new set of competition-based indicators that takes into account all relevant actors and helps understand broken and continued waves of technological development. Additionally, this study has shed new light on the dynamics of technological development during the early stages of socio-technical transition, and during the product life cycle's 'era of ferment' (Klepper, 1997).

6.1.2 What types of incumbents radically innovate

Chapter 3 addressed the question: **How did the incentive and opportunity to innovate affect incumbent car manufacturers' decision to mass market EVs over the period 1990–2011?** Based on a longitudinal patent and vehicle sales analysis, three periods of EV development could be identified over the study period: an R&D period (1990-1999), a period of inactivity (2000-2006) and a commercialization period (2007-2011). During the 1990s incumbent car manufacturers that were regulated by the full ZEV mandate developed a significantly stronger EV asset position, but did not sell significantly more EVs than their rivals. This apparent contradiction is remarkable – because the regulation mandated the sales of EVs – and suggests strategic behavior by the manufacturers subjected to the mandate. During the EV's commercialization period, large car manufacturers with both a strong incentive and a strong opportunity to innovate sold significantly more EVs than others. These firms adopted a first mover innovation strategy. Car manufacturers with some incentive and opportunity to innovate tended to pursue a quick follower strategy, whereas firms with either little incentive or little opportunity followed a laggard strategy.

This chapter contributes to the strategic management literature by linking innovation strategies to firms' opportunity and incentive to innovate, and by distinguishing between laggards that have the opportunity but not the incentive to innovate, and laggards that have the incentive but not the opportunity to innovate. The opportunity and incentive to innovate are related to the firm's available asset position, and its willingness to exploit it, respectively. By relating the incentive and opportunity to innovate to innovation strategies, we contribute to "a more practical resource-based theory about which resources and capabilities to deploy and which to keep in reserve" (Kraijenbroek et al., 2010, p.261), as laggards without incentive to radically innovate deploy their ICEV-based assets to yield profit, but keep their EV-based assets in reserve in case they need to respond to future market changes. The chapter's methodological contribution lies in providing more precise ways of operationalizing the opportunity to innovate. This study has furthered the discussion of incumbents' tendency to radically innovate (Chandy and Tellis, 2000; Lepore, 2014) by showing that they require both strong incentive and opportunity to innovate.

6.1.3 Political influence strategies of incumbents

Chapter 4 focused on the question: **What were the political strategies employed by incumbent car manufacturers and their political coalitions in response to the ZEV mandate, over the period 2000-2013?** The study showed that car manufacturers were initially very defensive towards the ZEV mandate. They tried to oppose, relax or slow down the mandate using CPAs like lobbying, commissioning studies to attack the mandate, litigation, having experts testify against the mandate, making EV demand seem smaller than it was, and delaying the regulatory process with multiple requests for data. However, over time their political strategies got less defensive and instead became oriented towards compliance with the mandate and proactively lobbying to shape the mandate in ways beneficial to the technologies they were investing in. The results indicate that the competitive forces identified in Chapter 2 are an important contributor to this change in car manufacturers' political strategy. Car manufacturers that invested in HFCVs for example, were lobbying to make the mandate more beneficial for HFCVs. Car manufacturers' coalitions did not change their political strategies and remained relatively defensive in their political actions as they continued to do the manufacturers' 'dirty work' to prevent reputational damage for their individual members.

This chapter contributes to the CPA literature and Oliver and Holzinger's (2008) framework on political strategies by showing how firms may combine different political strategies, and how these may change over time, partially because of competition. A contribution also lies with transition studies, in providing insights in the behavior of powerful incumbents and how they can influence the policy dimension of sustainability transitions. As competition helped to drive apart the previously closed industry front of opposition, competition can be seen as an important driver for sustainability transitions.

6.1.4 How incumbents combine innovation and political influence strategies

Chapter 5 addressed the research question: **How have incumbent car manufacturers combined and changed their innovation and political influence strategies in response to the ZEV mandate, over the period 1990-2013?** The study found that firstly, incumbent car manufacturers used specific combinations of innovation and political influence strategies, based on their value maintaining or value creating nature. This means that when incumbents tried to maintain the value of their assets through defensive political strategies, they tended to also maintain the value of their assets by not engaging in radical innovation. Innovative firms however, tried to create value not only through their stronger innovation strategies, but also by proactively shaping the mandate in ways that benefitted these innovation strategies. Secondly, incumbent car manufacturers changed their strategies and became more value creating over time. Hence, they became more innovative and more politically proactive instead of defensive towards the mandate. This is beneficial to the diffusion of and regulatory support for sustainable automotive technologies and thereby supports a transition towards a more sustainable automotive transportation system.

This chapter contributes to the CPA literature by refining the existing strategy typology through the identification of subclasses in defensive (opposition and slowdown) and proactive strategies (shaping, support and progressive) – see Table 6.1. This means that, ranging from strongly defensive to proactive political influence strategies, incumbents may oppose the mandate, slow it down, shape it, support it. Incumbents combine these respective political strategies with increasingly strong innovation strategies and thus generally move their strategies from left to right in Table 6.1, as indicated by the arrow. Only new entrants profiting from the regulation were found to employ progressive political influence strategies. Another important contribution of this chapter lies in integrating the literatures on innovation strategies and political influence strategies, to create a comprehensive framework on corporate response strategies to sustainability transitions supported by policy interventions.

Table 6.1: Corporate response strategies to technology-forcing regulation

		Value perspective				
		Value maintenance		Value creation		
Strategic orientation	Innovation (compliance)	**Reactive innovation strategy** *Cost-efficient compliance with technology-forcing regulation through laggard innovation strategies.*		**Anticipatory innovation strategy** *Anticipate stronger technology-forcing standards and stay ahead of regulatory change through first mover and quick follower innovation strategies.*		
		General direction of strategic change →				
	Political influence	**Defensive strategies:**		**Proactive strategies:**		
		Opposition *Oppose regulation to protect incumbent technology*	**Slowdown** *Slowdown and/or relax regulation for innovation strategy to 'catch up'*	**Shaping** *Shape regulation in favor of innovation strategy*	**Support** *Support the regulation because rivals have higher compliance costs*	**Progressive** *Increase stringency of regulation to increase rivals' compliance costs*

6.1.5 The changing role of incumbents in sustainability transitions

Now that the questions of each individual chapter have been addressed, the main research question of this dissertation – **What explains the expected dynamics in innovation and political influence strategies of incumbent car manufacturers in the field of clean vehicle technologies, over the period 1990-2013? –** may be answered.

This dissertation shows that incumbent car manufacturers did not engage seriously in clean vehicle technology innovation throughout the 1990s, but over time steadily increased their innovative efforts and started to invest in different emerging CVTs. Chapter 2 showed that competition was crucial in stimulating incumbents to do R&D in CVTs. Looking into the commercialization of EVs, Chapter 3 showed that especially incumbent car manufacturers that profited relatively little from the ICEV and that had already obtained assets to develop and commercialize EVs, were the ones to adopt first mover innovation strategies. In other words, incumbents require both strong incentive *and* opportunity to move early in radical innovation. Chapters 4 and 5 showed that as incumbents' innovation strategies became stronger and more diversified in different sustainable technologies, their political influence strategies changed accordingly. Their initially defensive strategies changed from opposing policy interventions, to slowing them down, to shaping them and even to supporting them. Following from Chapter 3, the decision to adopt a value maintaining or value creating innovation strategy is determined by the firm's incentive and opportunity to innovate. The shift from opposing policy to shaping policy in ways that favored their innovation strategies can be explained by the – in Chapter 2 identified – increasing technological competition in the field of sustainable automotive technologies.

To summarize, driven by strong regulation and competition, incumbent car manufacturers over time did more and more R&D in CVTs. Led by incumbents with the incentive and opportunity to radically innovate, these increasing R&D investments resulted in the commercialization of radically innovative EVs. Strong innovation strategies in different CVTs increased technological competition and triggered a shift in incumbent car manufacturers' political influence strategy from opposing and slowing down CVT-forcing regulation, towards shaping and supporting it. We can therefore conclude that incumbents' innovation and political influence strategies have co-evolved from value maintenance towards value creation.

These firm-level insights are important for transition scholars to understand the regime dynamics of sustainability transitions. Interpreted from a transitions perspective, we showed that technological competition, which constituted a destabilizing technological dimension to the regime, led to diverging interests amongst incumbents that broke apart the previously closed industry-front. This closed industry-front was an important stabilizing factor in the regime, not only because it constituted a stable industry dimension, but also because it inhibited change in the policy dimension. So, destabilization of the regime's technological dimension led to destabilization in the industry dimension, which created a window of opportunity for the policy dimension – now partly free of the industry's defensive influence – to change even more in favor of a sustainability transition. This narrative illustrates that powerful incumbents are indeed at the center of sustainability transitions and that their role changes over time, from doing little to support innovation and opposing policy developments to engaging in strong innovation and supporting policy developments.

6.2 Discussion and further research

This section critically reflects on the research approaches taken in this dissertation and the generalizability of its findings. Based on this discussion we provide some recommendations for further research.

In this dissertation, patents were selected as an indicator for R&D strategies and technological development because they are primarily used for protecting intellectual property, and because they are available over long time series, which facilitates longitudinal analyses. However, patents also have some drawbacks: the tendency to patent may differ over time and between countries, sectors, firms and technologies (Van den Hoed, 2005; Archibugi and Pianta, 1996). This was corroborated in an interview with a manager of Volkswagen, who explained their relatively low amount of patents with their pursuit of other IP protection strategies – such as secrecy. Like other patent studies, such firm-level differences could not be accounted for in this dissertation. Since patents remain often the most suitable indicator for R&D strategies, further research would profit greatly from finding ways to account for the differences in tendencies to patent.

In Chapters 4 and 5, the ZEV mandate was selected as a case study on incumbent car manufacturers' response to policy interventions that drive sustainability transitions. However, this mandate is unique in the sense that it forces the sales of a specific set of CVTs. This may have affected the strategic responses of these incumbents, as incumbents have the possibility to focus their political influence strategies on shaping the specific framework conditions and boundaries of each CVT compliance category. This focus on shaping the specifics created competition in car manufacturers' political influence strategies that we find has contributed to a trend away from industry opposition against the regulation. It should be noted, however, that with the emergence of new CVTs, other regulations are also starting to differentiate between specific CVTs in their regulatory conditions. For example, the European vehicular CO_2 emission standards have recently included super-credits for the more radical CVTs (EC, 2014). The ZEV mandate is therefore increasingly representative of policy interventions forcing CVTs, which enhances the generalizability of our findings. Nevertheless, the applicability of our conceptual model depicted in Table 6.1 should also be tested for different policy measures, like R&D and demand-pull initiatives, as less industry opposition would be expected in such cases.

Despite the increasing similarities in current regulations, Levy and Rothenberg (2002) find that broad institutional contexts have significantly affected strategic decisions of incumbent car manufacturers. In their comparison of European and US institutional contexts on car manufacturers' strategies, they find that there is less room in the EU for commissioning studies to influence policy making because people won't perceive them as independent. Also, economy-related arguments are less effective in the EU, because ministers of the environment have the capacity to formulate laws on sustainability (Levy and Rothenberg, 2002). Finally, US firms rely for their scientific input more on climate change critics, whereas German firms rely more on climate change advocates, which causes German car firms to be more aware of the need to become more sustainable (Levy and Rothenberg, 2002). Although the orientation of multinationals is becoming increasingly global, which diminishes the influence of national institutional differences, such institutional differences are still likely to have affected the innovation and political influence strategies of car manufacturers throughout the study period. The generalizability of our findings would thus greatly benefit from further research on incumbent car manufacturers' responses to policy interventions in different institutional contexts, e.g. in Europe and Japan.

It is likely that many of our findings on the strategic responses of powerful incumbent car manufacturers to sustainability transitions apply to all powerful incumbents that dominate their respective sectors and have vested interests that are threatened by a sustainability transition. However, such generalizations require further research, for example in the oil sector, the electricity sector and the construction sector.

For new technologies to successfully overtake established technologies, change is required in all dimensions of the regime: industry, policy, markets, science and culture need to co-evolve (Geels, 2002; Grin et al., 2010). In terms of the RDT, to successfully innovate, innovators are dependent on the diverse array of organizations that comprise their environment and they are likely to manage their environment by influencing these organizations. This dissertation focused on how incumbents changed their value maintaining and value creating strategies in response to changes in the technological and policy dimensions of the regime. However, as sustainability transitions require change in all regime dimensions (Geels, 2002; Grin et al., 2010), incumbents' strategies in response to changes in the other regime dimensions are relevant as well. Therefore, we propose further research to complement our findings by studying incumbents' response to the changing industry dimension (industry structures may change through for example new entrants and late industry shake-outs) using strategies explored by the RDT, like vertical integration, partnering, incorporating important actors in boards of directors and executive succession (Hillman et al., 2009; Pfeffer and Salancik, 1987). Further research could also focus on incumbents' role in changing the market dimension by for example studying their advertising and pricing strategies. Incumbents' response to the changing science dimension could also be studied by analyzing how they confirm or create doubt about issues like climate change that are at the core of sustainability transitions, see Oreskes and Conway (2010). Finally, further research could focus on incumbents' response to the culture dimension by studying how influencing and exploit public perception regarding sustainability through information strategies, grassroots mobilization, framing and 'green washing' (Van den Hoed, 2005). It would be interesting to study whether the response strategies towards changes in these other regime dimensions show the same co-evolutionary dynamics as we found in the innovation and political influence strategies. Studying incumbents' response strategies towards these other changing regime dimensions would lead to a better understanding of the different roles incumbents play in (sustainability) transitions.

6.3 Policy recommendations

Based on the studies conducted in this dissertation, several recommendations can be made to policy makers.

In Chapter 3 it was found that incumbents that profit least from the established technology are the ones to first commercialize radically new, sustainable technologies because they have the most incentive to do so. These firms had a competitive disadvantage compared to their rivals that resulted from the established technology, and radical innovations were for them a means to overthrow established competitive positions. Based on this finding, policy makers are recommended to issue demand-pull policy interventions that support these radical and sustainable innovations. This can be done by shaping public and customer opinion in favor of these innovations, and by providing financial, infrastructural and other regulatory support such as preferential parking. Such policy interventions will enhance the chances of success of radical innovations on which the currently less profitable firms can becoming increasingly dependent, thereby enhancing their economic viability in a way that does not discriminate between firms and that contributes to sustainability transitions. Supporting the less profitable firms in their potential innovation strategies reduces their chance of failing and prevents the associated loss of jobs.

Chapters 4 and 5 found that demand-pull policy interventions are particularly effective when combined with technology-forcing policy interventions in a so called 'carrot and stick' approach to policy making, because it reduces industry opposition to technology-forcing regulations. Although cheap and effective in supporting new, sustainable technologies (Lee et al., 2010), technology-forcing regulations create a lot of industry opposition because they are often costly for firms to comply with and because they tend to drive firms away from their profitable position. Representatives of incumbents and of incumbents' industry associations indicated that complementing technology-forcing regulations with demand-pull initiatives would signal that governments were also committed to the new technologies, instead of just 'throwing the problem over the fence' and letting industry solve it. Such commitment would incentivize industry to cooperate in the issuance of technology-forcing policy interventions.

Another policy recommendation to reduce industry opposition to technology-forcing regulations is for policy makers to interact more with individual firms to gain support for their regulations. This recommendation is based on our finding in Chapter 4 that lobbying coalitions and industry associations are, and over time continue to be, more defensive in their political strategies than individual firms. Individual firms are less likely to oppose policy because they do not want to suffer the image penalty of doing so.

The final policy recommendation of this dissertation is that technology-forcing regulations aimed at driving sustainability transitions should be formulated in broad, general terms but at the same time should differentiate between specific sustainable technologies. The ZEV mandate is a good illustration as it mandated a general amount of clean vehicle credits that could be met by selling different types of CVTs, each with their specific credit multipliers. A somewhat similar approach is adopted in the European vehicular CO_2 emission standards, which provide broad emission standards, but have included super-credits for the more radical CVTs, like EVs (EC, 2014). This combination of broad general requirements and higher credit multipliers for more desirable technologies leaves room for technological competition which, Chapters 4 and 5 indicated, helps break apart the closed industry-front of opposition. By meeting, to some extent, the policy demands of individual firms, for example by creating higher credits for the societally desirable technologies they are investing in, competition can also be generated in the policy arena. This political competition between firms trying to shape the regulation in ways favorable to their individual compliance and innovation strategies will replace their initial opposition and creates room for subsequently ramping up the regulation.

To conclude, various studies have pointed out that technology-forcing regulations are very effective in bringing sustainable technologies to the market (Van Vorst and George, 1997; Taylor et al., 2005; Lee et al., 2010). However, policy makers need to be perseverant in maintaining such policy and withstand initial industry opposition. Eventually, as innovations develop and technological competition takes place, industry opposition will break down.

Summary

Our society faces many sustainability problems that are related to its dependence on fossil fuels, including local air pollution, climate change through excessive greenhouse gas emissions, and security of the oil supplies that drive our economy. Effectively addressing these large scale sustainability problems requires sustainability transitions: deep-structural changes in the socio-technical regime that is comprised of a stable configuration of interacting dimensions, including technology, markets, politics, culture, and science. Only when all components co-evolve, will new sustainable technologies have a chance of overtaking the established, polluting technologies. However, sustainability transitions are hampered for three reasons: 1) 'sustainability' is a collective good, causing free rider problems and prisoner's dilemmas, 2) established technologies outperform sustainable solutions in terms of individual consumer benefits, 3) polluting sectors are dominated by powerful incumbents that have no incentive to develop and diffuse new, sustainable technologies since these technologies often constitute radical innovations that render obsolete many of their existing competences.

For sustainability transitions to have a chance of succeeding, policy interventions are necessary to overcome these problems. Particularly technology-forcing policy interventions are effective in driving powerful incumbents to (radically) innovate. However, these incumbents have a history of opposing such policy interventions, through political influence strategies, to protect their profitable position. Nevertheless, some incumbents are also known to engage in radical innovation. This apparent contradiction indicates that powerful incumbents may play different roles in sustainability transitions: on the one hand they may hamper transitions by opposing policy interventions; on the other hand they may drive transitions by engaging in radical innovation. To understand how firm-level dynamics affect sustainability transitions, in this dissertation we study the role of incumbents, how it potentially changes over time as well as why some incumbents radically innovate and others do not.

To create a conceptual framework that takes into account these different roles of powerful incumbents, we build on the resource based view (RBV) and the resource dependence theory (RDT). The RBV perceives firms as bundles of assets

(i.e. resources that are valuable, rare, inimitable and nonsubstitutable) that determine their competitive advantage. When the firm's environment changes, as in the case of sustainability transitions, firms need to adapt their assets to maintain the value of their assets and sustain their competitive advantage. To exploit changes in their environment firms can adopt different innovation strategies – related to their development of technological assets and timing to market. Strong innovation strategies involve extensive adaptation of assets to create new value for the firm, while weak innovation strategies involve maintaining the value of existing assets through marginal adaptation.

The RDT suggests that to survive, firms influence the different types of organizations that make up their environment. The corporate political activities (CPA) literature, embedded within the RDT, focuses on how firms influence the regulatory environment through actions like lobbying, litigation, financial contributions, constituency building and utilizing political networks. Incumbents with political influence strategies utilize CPAs to shape regulations that drive sustainability transitions, either to maintain value in a defensive political strategy, or to create value in a proactive strategy. Firms engaging in defensive political influence strategies oppose regulations that threaten their firm's value and try to maintain the favorable status quo. Proactive political influence strategies are intended to shape regulations so that they support the firm's creation of new value and enhance their strong innovation strategies.

Based on the distinction between innovation and political influence strategies and between value maintaining and creating strategies, a conceptual framework on incumbents' response strategies to policy interventions driving sustainability transitions was proposed.

The automotive transportation system is one of the most polluting sectors and therefore an interesting case study. This dissertation focuses on incumbent car manufacturers because they dominate this sector and are able to influence both technological as well as public policy developments. A sustainability transition in this sector would require the development and diffusion of sustainable and radically new clean vehicle technologies (CVTs)[9], such as plug-in hybrids, full-

9 In 'Appendix I – Technical explanation of powertrains' a short technical explanation of the different CVTs is provided; 'Appendix II – List of abbreviations' provides an overview of all acronyms used in this dissertation.

electric vehicles (EVs) and hydrogen fuel cell vehicles (HFCVs). To study how incumbent car manufacturers' responded to CVT-forcing regulations, the case of the zero emission vehicle (ZEV) mandate in California was selected, because it is very influential and has been subjected to industry influence over the study period 1990-2013. This mandate forces car manufacturers to market CVTs as a given percentage of their total car sales. The research question central to this dissertation is: **What explains the expected dynamics in innovation and political influence strategies of incumbent car manufacturers in the field of clean vehicle technologies, over the period 1990-2013?**

Chapter 2 addresses the question: **How did the forces of rivalry, dispersion and the presence of new entrants affect the duration of earlier waves of development of CVTs and how do these competitive forces affect the chances of continuation of the current wave of EV development?** Waves of technological development are the result of increases and subsequent decreases in R&D investments, caused by firms' shifting R&D strategies. The automotive sector has known several waves of development of CVTs, most of which were short-lived. To study whether the current wave of EV development will break or continue, in this chapter a set of competition-related factors are established that are hypothesized to increase the length of waves of technological development, as empirical evidence suggests that strong competition drives firms to investment in R&D. These factors include rivalry – i.e. competition between the same type of incumbent firms; dispersion – referring to competition in general, between all types of organizations; the presence of new entrants that challenge incumbents.

Based on a longitudinal patent analysis using improved search queries, we identified four waves of CVT development over the period 1990–2010. Two of these waves, those of EV development (1990-1994) and HFCV development (1998-2007), were broken before becoming a commercial success. The wave of HEV development, starting in 1996 was continued and became a commercial success. The fourth wave is the current wave of EV development. Although the presence of new entrants could not be tested on all waves of development, our findings suggest that the combination of rivalry and dispersion positively relates to waves of continued technological development. We did find that new entrants accounted for most of the patent increase during the current wave of EV development. We conclude that current EV developments are driven by rivalry and competition amongst an increasing number of organizations, including new entrants. We expect that through competitive pressures these organizations continuously trigger each other to invest more in the technological development of the EV, which will sustain this wave of EV development. This study also finds that incumbent car manufacturers dominate HEV and HFCV development, but that a wide array of different firms explores EV development. Such wide dispersion of EV development has an entry-barrier-lowering effect that might explain the large number of new entrants.

This chapter has contributed to technological forecasting by providing a new set of competition-based indicators that takes into account all relevant actors and helps understand broken and continued waves of technological development. Additionally, this study has shed new light on the dynamics of technological development during the early stages of socio-technical transition, and during the product life cycle's era of ferment.

Chapter 3 addresses the research question: **How did the incentive and opportunity to innovate affect incumbent car manufacturers' decision to mass market EVs over the period 1990–2011?** This question is relevant to establish why some incumbent car manufacturers do and others do not radically innovate in the field of EVs – as the tendency of incumbents to radically innovate is, as of recently, heavily debated. Firms require both incentive and opportunity to innovate and although incumbents may have the opportunity to radically innovate, they often lack the incentive. We approach the incumbent's incentive to innovate by its profit in the field of the established ICEV technology, since we expect that incumbents profiting a lot from the established technology have little incentive to overthrow their own profitable position through radical innovation. A firm's opportunity to innovate was measured by the assets it had developed to exploit EVs, i.e. its EV asset position, which provides a more precise measure than the normally used measure of capital available for R&D. Based on the focal incumbent's timing of EV commercialization, we distinguish between first mover, quick follower and laggard innovation strategies.

During the 1990s incumbent car manufacturers that were regulated by the full ZEV mandate developed a significantly stronger EV asset position, but did not sell significantly more EVs than their rivals. During the EV's commercialization period (2007-2011), large car manufacturers with both a strong incentive and a strong opportunity to innovate sold significantly more EVs than others. These firms adopted a first mover innovation strategy. Car manufacturers with some incentive and opportunity to innovate tended to pursue a quick follower strategy, whereas firms with either little incentive or little opportunity followed a laggard strategy.

This chapter contributes to the strategic management literature by linking innovation strategies to firms' opportunity and incentive to innovate, and by distinguishing between laggards that have no incentive and laggards that have no opportunity to innovate. This study has furthered the discussion of incumbents' tendency to radically innovate by showing that they require both strong incentive and opportunity to innovate.

The research question addressed in Chapter 4 is: **What were the political strategies employed by incumbent car manufacturers and their political coalitions in response to the ZEV mandate, over the period 1990-2013?** The study consults the CPA literature to frame these political strategies, their underlying tactics and the actions through which they respond to regulation – for whic. Using an extensive database of 268 documents and 16 interviews, we identify different types of compliance actions and CPAs, of which 1038 lobbying-comments.

The results indicate that car manufacturers were initially very defensive towards the ZEV mandate. They tried to oppose, relax or slow down the mandate using CPAs like lobbying, commissioning studies to attack the mandate, litigation, having experts testify against the mandate, making EV demand seem smaller then it was, and delaying the regulatory process with multiple request for data. However, over time their political strategies got less defensive and instead became oriented towards compliance with the mandate and proactively lobbying to shape the mandate in ways beneficial to the CVTs they were investing in. Car manufacturers investing in HFCVs for example, were lobbying to make the mandate less stringent for HFCVs. Car manufacturers' coalitions did not change their political strategies and remained relatively defensive in their political actions as they continued to do the manufacturers' 'dirty work' to prevent reputational damage for their individual members.

This chapter contributes to the CPA literature and the framework on political strategies by showing how firms may combine different political strategies, and how these may change over time, partially as a result of competition. A contribution also lies with transition studies, in showing the extent to which powerful incumbents can influence the policy dimension of sustainability transitions, particularly in a negative way. The study shows that competition helped drive apart the previously closed industry front of opposition and is therefore an important driver for sustainability transitions.

Chapter 5 addressed the research question: **How have incumbent car manufacturers combined and changed their innovation and political influence strategies in response to the ZEV mandate, over the period 1990-2013?** The interaction between and change of innovation and political influence strategies has received little attention. This chapter studies such interaction through the previously discussed conceptual framework on innovation and political influence strategies. The study combines and complements all data collected in the previous chapters; we use patent and sales data to operationalize the R&D and commercialization aspects of innovation strategies in CVTs, while using CPA-data to operationalize political influence strategies.

The study finds that firstly, incumbent car manufacturers used specific combinations of innovation and political influence strategies, along their value maintaining or value creating nature. This means that when firms try to maintain the value of their assets through defensive political strategies, they tend to also maintain value by doing little innovation. Innovative firms however, try to create value not only through their innovation strategy, but also by proactively shaping the mandate in ways that benefit these innovation strategies. Secondly, incumbent car manufacturers changed their strategies and became more value creating over time. Hence, they became more innovative and more politically proactive instead of over time, which is beneficial to the diffusion of and regulatory support for CVTs and to a broader sustainability transition.

This chapter contributes to the CPA literature by refining existing strategy typology through the identification of subclasses in defensive (opposition and slowdown) and proactive strategies (shaping, support and progressive)

– see Table 1. This means that, ranging from strongly defensive to proactive political influence strategies, incumbents may oppose the mandate, slow it down, shape it or support it. Incumbents combine these respective political strategies with increasingly strong innovation strategies and thus generally move their strategies from left to right in Table 1, as indicated by the arrow. Only new entrants profiting from the regulation were found to progress it (i.e. make it more stringent). Another important contribution of this chapter lies in integrating the literatures on innovation strategies and political influence strategies, to create a comprehensive framework on corporate response strategies to sustainability transitions supported by policy interventions.

Table 1: Corporate response strategies to technology-forcing regulation

		Value perspective				
		Value maintenance		Value creation		
Strategic orientation	Innovation (compliance)	**Reactive innovation strategy** *Cost-efficient compliance with technology-forcing regulation through laggard innovation strategies.*		**Anticipatory innovation strategy** *Anticipate stronger technology-forcing standards and stay ahead of regulatory change through first mover and quick follower innovation strategies.*		
		General direction of strategic change →				
	Political influence	**Defensive strategies:**		**Proactive strategies:**		
		Opposition *Oppose regulation to protect incumbent technology*	**Slowdown** *Slowdown and/or relax regulation for innovation strategy to 'catch up'*	**Shaping** *Shape regulation in favor of innovation strategy*	**Support** *Support the regulation because rivals have higher compliance costs*	**Progressive** *Increase stringency of regulation to increase rivals' compliance costs*

This dissertation concludes that, at least for incumbent car manufacturers that dominate the automotive sector, incumbents play different roles in sustainability transitions, through their innovation and political influence strategies. These incumbents started out hampering transition, by opposing change in the policy component and refraining from changing the technological component. But, eventually the incumbents became an important driver to transition by changing the technological component of the regime and supporting changes in the policy component. The system-level change from bottleneck to driver to transition was caused by a firm-level strategic shift that was reinforced by technological competition. As incumbents developed different technologies, their interests diverged increasingly. Incumbents with the incentive and opportunity to radically innovate were the first to support a sustainability transition of the automotive transportation system through commercialization activities. The increasingly diverging interests led not only to competition in the technological component of the regime, but also to competition in the policy component –firms were competing to influence the policy intervention in ways that were favorable to their own innovation strategy and/or that disfavored the innovation strategies of their rivals.

Further research should test the generalizability of this explorative case study's findings on incumbents' innovation and political influence strategies, to other policies within the automotive sector and to other sectors. Moreover, we focused on the role of incumbents in the changing policy and technology dimensions of the regime, but it would be interesting to also study their role in the changing industry, market, scientific and cultural dimensions of the regime.

To deal with industry opposition to policy interventions, this research suggests that policy makers focus their interaction with industry on individual firms instead of industry associations, craft policies that stimulate competition between firms to break apart their closed industry front, and complement technology-forcing policies with demand-pull initiatives. Demand-pull initiatives also support the less profitable incumbents in their risky radical innovation strategies, reducing their chance of failure and the accompanying loss of jobs.

Samenvatting

Onze samenleving kampt met veel duurzaamheidsproblemen die gerelateerd zijn aan onze afhankelijkheid van fossiele brandstoffen; hieronder vallen lokale luchtvervuiling, klimaatverandering door hoge uitstoot van broeikasgassen, en de beschikbaarheid van de olievoorraden die onze economie in stand houden. Duurzaamheidstransities zijn nodig om deze grootschalige duurzaamheidsproblemen aan te pakken. Transities zijn structurele veranderingen in het socio-technische regime die over een periode van enkele generaties (25-50 jaar) plaatsvinden en meerdere dimensies omvatten. Deze dimensies zijn: technologie, markten, politiek, cultuur en wetenschap. Alleen wanneer deze dimensies co-evolueren, zullen nieuwe duurzame technologieën een kans hebben om de gevestigde, vervuilende technologieën te vervangen. Duurzaamheidstransities worden echter om drie redenen belemmerd: 1) 'duurzaamheid' is een collectief goed, waardoor dilemma's van collectieve actie en 'prisoner dilemmas' ontstaan, 2) gevestigde technologieën zijn vaak beter dan duurzame oplossingen in termen van voordelen voor de consument, en 3) vervuilende sectoren worden gedomineerd door machtige gevestigde bedrijven die een geringe prikkel hebben om nieuwe, duurzame technologieën te ontwikkelen en te verspreiden. Deze technologieën zijn namelijk vaak radicale innovaties die de competenties die gevestigde bedrijven ontwikkeld hebben waardeloos maken.

Beleidsmaatregelen zijn nodig om deze problemen te verminderen en om duurzaamheidstransities een kans van slagen te geven. Vooral beleid dat duurzame technologieën de markt op forceert lijkt effectief om machtige gevestigde bedrijven (radicaal) te laten innoveren. Echter, om hun winstgevende positie te beschermen hebben deze gevestigde bedrijven zich in het verleden sterk verzet tegen dergelijk beleid, door middel van politieke beïnvloedingsstrategieën. Toch is van enkele gevestigde bedrijven bekend dat zij radicaal innoveren. Deze schijnbare tegenstrijdigheid geeft aan dat machtige gevestigde bedrijven verschillende rollen kunnen spelen in duurzaamheidstransities. Aan de ene kant kunnen zij transities belemmeren door zich tegen beleidsinterventies te verzetten. Aan de andere kant kunnen zij transities faciliteren door nieuwe, duurzame technologieën te ontwikkelen en te verkopen. Om te begrijpen hoe dergelijke strategieën op bedrijfsniveau

duurzaamheidstransities beïnvloeden, bestuderen we in dit proefschrift de strategieën van gevestigde bedrijven in transities, hun beweegredenen en de mogelijke strategische veranderingen in de tijd.

Om een conceptueel kader te creëren dat rekening houdt met de mogelijk verschillende rollen van machtige gevestigde bedrijven, bouwen we voort op de resource-based view (RBV) en de resource dependence theorie (RDT). De RBV ziet bedrijven als pakketjes van waardevolle, zeldzame, niet-imiteerbare en niet-vervangbare middelen die hun concurrentiepositie bepalen. Wanneer de omgeving van het bedrijf verandert, zoals in het geval van duurzaamheidstransities, moeten bedrijven hun middelen aanpassen om de waarde van deze middelen te behouden en zo hun concurrentiepositie in stand te houden. Om veranderingen in hun omgeving te exploiteren, kunnen bedrijven innovatiestrategieën kiezen op het gebied van welke technologische middelen ze ontwikkelen en wat de timing van markttoetreding is. Sterke innovatiestrategieën omvatten de aanpassing van middelen om nieuwe waarde voor het bedrijf te ontwikkelen en vroege markttoetreding mogelijk te maken, terwijl zwakke innovatiestrategieën het behoud van de waarde van bestaande middelen ten doel hebben via minimale aanpassing en door laat toe te treden op de markt voor radicale innovaties.

De RDT suggereert dat bedrijven de verschillende soorten organisaties die deel uitmaken van hun omgeving moeten beïnvloeden om te overleven. De bedrijfspolitieke activiteiten (CPA) literatuur, ingebed in de RDT, bestudeert hoe bedrijven regelgeving kunnen beïnvloeden door middel van CPA's zoals lobbyen, rechtszaken aanspannen, financiële bijdragen leveren, en het exploiteren van kiessteun en politieke netwerken. Gevestigde bedrijven kunnen regelgeving beïnvloeden met politieke beïnvloedingsstrategieën die trachten de waarde van hun bedrijfsmiddelen te behouden of die trachten nieuwe waarde te creëren. Ondernemingen die defensieve politieke beïnvloedingsstrategieën hanteren verzetten zich tegen regelgeving die de waarde van hun bedrijf bedreigt; zij proberen de gunstige bestaande situatie te handhaven. Proactieve politieke beïnvloedingsstrategieën zijn bedoeld om regelgeving vorm te geven, zodat ze de nieuwe waarde creatie van het bedrijf – en daarmee hun innovatiestrategie – ondersteunen.

We ontwikkelen een conceptueel raamwerk om te bestuderen wat de strategische reacties zijn van gevestigde bedrijven met betrekking tot beleidsinterventies die duurzaamheidstransities trachten te faciliteren. Dit raamwerk maakt onderscheid tussen innovatie- en politieke beïnvloedingsstrategieën en tussen waardebehoudende en waardecreërende strategieën.

Het auto-transportsysteem is een van de meest vervuilende sectoren en is daarom een interessante case studie in de context van duurzaamheidstransities. Dit proefschrift richt zich op gevestigde autofabrikanten omdat zij de autosector domineren en zowel de ontwikkeling van beleid als van technologie kunnen beïnvloeden. Een duurzaamheidstransitie in deze sector vereist de ontwikkeling en verspreiding van duurzame en radicaal nieuwe automobieltechnologieën, zoals plug-in hybrides (PHEV's)[10], volledig elektrische voertuigen (EV's) en waterstofbrandstofcel voertuigen (HFCV's). Om de politieke beïnvloedingsstrategieën van gevestigde autofabrikanten te bestuderen, werd de case van het emissieloze voertuigen (ZEV) mandaat in Californië gekozen. Dit mandaat verplicht autofabrikanten tot de verkoop van nieuwe duurzame automobieltechnologieën als een percentage van hun totale verkoop. De centrale onderzoeksvraag van dit proefschrift is: **Wat verklaart de verwachte dynamiek in innovatie- en politieke beïnvloedingsstrategieën van gevestigde autofabrikanten op het gebied van duurzame automobieltechnologieën, over de periode 1990-2013?**

Hoofdstuk 2 gaat in op de vraag **'Hoe hebben de concurrentiefactoren rivaliteit, dispersie en de aanwezigheid van nieuwe toetreders de duur van de eerdere golven van ontwikkeling van duurzame automobieltechnologieën beïnvloed, en hoe beïnvloeden deze factoren de kans op voortzetting van de huidige golf van EV ontwikkeling?'** Golven van technologische ontwikkeling zijn het gevolg van stijgingen en vervolgens dalingen in R&D investeringen, veroorzaakt door veranderende R&D strategieën van bedrijven. Onderzoek toont aan dat sterke concurrentie bedrijven stimuleert om meer in R&D te investeren en kan daarmee golven van ontwikkeling verlengen. Als verschillende concurrentie-factoren onderscheiden wij rivaliteit – dat wil

10 In 'Appendix I – Technical explanation of powertrains' wordt teen korte technische beschrijving gegeven van de verschillende duurzame autotechnologieën. De sectie 'Appendix II – List of abbreviations' geeft een overzicht van alle afkortingen die gebruikt worden in dit proefschrift.

zeggen de concurrentie tussen hetzelfde type bedrijf, dispersie - concurrentie tussen alle soorten bedrijven, en de aanwezigheid van nieuwe toetreders die gevestigde bedrijven uitdagen. De autosector heeft verschillende golven van de ontwikkeling van duurzame automobieltechnologieën gekend, waarvan de meeste van korte duur waren. Om te onderzoeken of de huidige golf van EV ontwikkeling vroegtijdig zal afbreken of langdurig zal voortduren, wordt in dit hoofdstuk bestudeerd hoe de aanwezigheid van rivaliteit, dispersie en nieuwe toetreders samenhangt met de lengte van de golven van ontwikkeling van duurzame automobieltechnologieën.

Op basis van een longitudinale patent analyse identificeerden we voor duurzame automobieltechnologieën over de periode 1990-2010 vier golven van ontwikkeling. Twee van deze golven, die van EV ontwikkeling (1990-1994) en van HFCV ontwikkeling (1998- 2007), werden afgebroken voordat ze een commercieel succes werden. De golf van HEV ontwikkeling, die begon in 1996 zette zich langdurig voort en leidde tot een commercieel succes van de HEV. De vierde golf is de huidige golf van EV ontwikkeling. Wegens gebrek aan data voor de eerdere perioden van ontwikkeling konden we de invloed van de aanwezigheid van nieuwe toetreders niet testen voor alle golven van ontwikkeling. We vinden wel dat de combinatie van rivaliteit en dispersie positief correleert met de lengte van golven van technologische ontwikkeling. We vonden verder dat nieuwe toetreders verantwoordelijk zijn voor het grootste deel van de stijging in patenten van de huidige golf van EV ontwikkeling. We concluderen dat de huidige EV ontwikkelingen worden gedreven door rivaliteit en concurrentie tussen een toenemend aantal organisaties, waaronder nieuwe deelnemers. We verwachten dat deze organisaties door de concurrentiedruk elkaar continu stimuleren om meer te investeren in de technologische ontwikkeling van de EV, ook op de lange termijn. Deze studie toont ook dat de gevestigde autofabrikanten de HEV en HFCV ontwikkeling domineren, maar dat een breed scala van verschillende bedrijven bijdraagt aan EV ontwikkeling. Een dergelijke brede spreiding van EV ontwikkeling heeft een toetredingsbarrière-verlagend effect, wat het grote aantal nieuwe toetreders zou kunnen verklaren.

Dit hoofdstuk heeft bijgedragen aan technologievoorspelling door een nieuwe set van op concurrentie gebaseerde factoren te introduceren die alle relevante actoren omvat en helpt begrijpen waarom bepaalde golven van technologische ontwikkeling vroegtijdig afgebroken worden en andere langdurig worden voortgezet. Bovendien heeft deze studie nieuw licht geworpen op de dynamiek van technologische ontwikkeling gedurende de vroege stadia van socio-technische transities.

Hoofdstuk 3 gaat in op de onderzoeksvraag **'Hoe hebben de prikkel en kans voor innovatie de beslissing van gevestigde autofabrikanten om EV's te commercialiseren beïnvloed in de periode 1990-2011?'** Omdat de neiging van gevestigde bedrijven om radicaal te innoveren sterk bediscussieerd wordt, is deze onderzoeksvraag belangrijk om vast te stellen waarom bepaalde gevestigde autofabrikanten radicaal innoveren op het gebied EV's en andere niet. Bedrijven hebben zowel een prikkel als een kans nodig om radicaal te innoveren. Hoewel gevestigde bedrijven mogelijk de kans voor radicale innovatie hebben, ontbreekt het hen vaak aan de prikkel. De prikkel voor radicale innovatie wordt voor gevestigde bedrijven gemeten met de winst die zij halen uit de bestaande interne verbrandingsmotortechnologie. De verwachting is namelijk dat gevestigde bedrijven die veel verdienen aan de bestaande technologie een geringe prikkel hebben om hun eigen winstgevende positie te ondermijnen door radicaal te innoveren. De kans op radicale innovatie werd gemeten met de middelen die het bedrijf had ontwikkeld om EV's te exploiteren: de EV middelenpositie. Deze maat is nauwkeuriger dan de normaal gebruikte indicator – het kapitaal dat een bedrijf beschikbaar heeft voor R&D. Gebaseerd op de timing van EV commercialisatie maken we onderscheid tussen pionier, snelle volger en achterblijver innovatiestrategieën.

Tijdens de jaren 1990 ontwikkelden gevestigde autofabrikanten die werden gereguleerd onder het volledige ZEV mandaat een duidelijk sterkere EV middelenpositie, maar verkochten vreemd genoeg niet significant meer EV's dan hun rivalen. Tijdens de commercialiseringsperiode van de EV (2007-2011), verkochten gevestigde autofabrikanten met zowel een sterke prikkel als kans voor innovatie significant meer EV's dan hun rivalen. Deze bedrijven hanteerden een pioniers innovatiestrategie. Autofabrikanten met een matige prikkel en kans voor innovatie volgden doorgaans een snelle volger strategie, terwijl bedrijven met ofwel weinig prikkel ofwel weinig kans voor innovatie een achterblijver strategie kozen.

Dit hoofdstuk draagt bij aan de strategische management literatuur door innovatiestrategieën te koppelen aan de prikkel en kans voor innovatie, en door onderscheid te maken tussen de achterblijvers zonder prikkel om te innoveren en achterblijvers zonder kans om te innoveren. Deze studie draagt bij aan de discussie of gevestigde bedrijven wel of niet innoveren, door te laten zien dat radicaal innoverende gevestigde bedrijven zowel een sterkere prikkel als kans voor innovatie hebben dan hun rivalen.

De onderzoeksvraag van Hoofdstuk 4 luidt: **'Wat waren de politieke strategieën van gevestigde autofabrikanten en hun politieke coalities in reactie op het ZEV mandaat, over de periode 2000-2013?'** Voor het conceptualiseren van de politieke strategieën, de onderliggende tactieken en de acties waarmee autofabrikanten reageren op het ZEV mandaat, put deze studie uit de CPA literatuur. Met behulp van een uitgebreide database van 268 documenten en 16 interviews, identificeren we verschillende soorten nalevingsacties en beïnvloedingacties (CPA's), waaronder 1.038 commentaren op het mandaat.

De resultaten geven aan dat autofabrikanten aanvankelijk zeer defensief waren naar het ZEV mandaat. Ze probeerden het mandaat ongedaan te maken en, toen dit niet mogelijk bleek, het mandaat te verzwakken en te vertragen door middel van CPA's zoals lobbyen, studies laten uitvoeren om het mandaat aan te vallen, rechtszaken aanspannen, deskundigen laten getuigen tegen het mandaat, de vraag naar EVs kleiner laten lijken dan die was, en met meerdere verzoeken om extra data die het mandaat ondersteunden. Echter, na verloop van tijd werden hun politieke strategieën minder defensief en meer gericht op 1) de naleving van het mandaat en 2) het proactief vormgeven van het mandaat op een manier die gunstig was voor de technologieën waarin de autofabrikanten om dat moment investeerden. Autofabrikanten die in HFCVs investeerden lobbyden bijvoorbeeld proactief om het mandaat aantrekkelijker te maken voor HFCVs. In tegenstelling tot de individuele autofabrikanten veranderden de coalities van autofabrikanten hun politieke strategieën niet. Zij bleven defensief in hun politieke acties en deden het 'vuile werk' voor de autofabrikanten om reputatieschade voor hun individuele leden te voorkomen.

Dit hoofdstuk draagt bij aan de CPA literatuur, door te laten zien hoe bedrijven verschillende politieke strategieën kunnen combineren, en hoe deze kunnen veranderen in de tijd, gedeeltelijk als gevolg van concurrentiedruk. Er is ook een bijdrage aan transitiestudies, door te tonen hoe machtige gevestigde bedrijven de beleidsdimensie van duurzaamheidstransities beïnvloeden. De studie toont aan dat onderlinge concurrentie het eerder gesloten industriefront uit elkaar dreef; concurrentie is daarom een belangrijke drijfveer voor het laten slagen van duurzaamheidstransities.

Hoofdstuk 5 gaat in op de onderzoeksvraag **'Hoe hebben gevestigde autofabrikanten hun innovatie- en politieke beïnvloedingsstrategieën gecombineerd en veranderd in reactie op het ZEV mandaat, over de periode 1990-2013?'** De interactie tussen, en veranderingen van innovatie- en politieke strategieën heeft weinig aandacht gekregen in de literatuur. Dit hoofdstuk bestudeert deze interactie via een conceptueel raamwerk dat onderscheid maakt tussen innovatie- en politieke beïnvloedingsstrategieën en tussen waardebehoudende en waardecreërende strategieën. Waardebehoud verwijst naar het behouden van de huidige situatie en het beschermen van de bestaande bedrijfsmiddelen. Waardecreatie verwijst naar het voorop lopen in de exploitatie van veranderingen in de omgeving. De studie combineert en complementeert alle in de voorgaande hoofdstukken verzamelde gegevens. Patent- en verkoopdata werden gebruikt om de respectievelijke R&D- en marketingaspecten van innovatiestrategieën in schone automobieltechnologieën te meten, terwijl CPA-data gebruikt werden om politieke beïnvloedingsstrategieën te operationaliseren.

Uit de studie blijkt in de eerste plaats, dat gevestigde autofabrikanten specifieke combinaties van innovatie en politieke beïnvloedingsstrategieën hanteerden, op basis van hun waardebehoudende of waardecreërende aard. Dit betekent dat wanneer bedrijven probeerden de waarde van hun middelen te behouden met behulp van defensieve politieke strategieën, ze doorgaans ook waarde behielden door weinig te innoveren. Innovatieve bedrijven probeerden echter niet alleen waarde te creëren door middel van sterke innovatiestrategieën, maar ook door proactieve politieke beïnvloedingsstrategieën gericht op het vormgeven van het mandaat op een manier die hun innovatiestrategieën ondersteunde. Ten tweede, gevestigde autofabrikanten hanteerden, naarmate de tijd vorderde, steeds vaker waardecreërende strategieën. Ze werden dus innovatiever en politiek meer proactief en ondersteunend over de tijd. Dit is gunstig voor de verspreiding van duurzame automobieltechnologieën en voor de ontwikkeling van ondersteunende regelgeving, hetgeen duurzaamheidstransities faciliteert.

Dit hoofdstuk draagt bij aan de CPA literatuur door de bestaande strategie typologie te verfijnen door het aangeven van subklassen in de defensieve (oppositie en vertragen) en proactieve strategieën (vormgeven, ondersteunen en progressief) - zie Tabel 1. Dit betekent dat, oplopend van sterk defensieve tot proactieve politieke beïnvloedingsstrategieën, gevestigde bedrijven zich tegen het mandaat kunnen verzetten, het mandaat kunnen vertragen, het kunnen vormgeven of steunen. Gevestigde bedrijven combineerden deze politieke strategieën met respectievelijk steeds sterkere innovatiestrategieën. Ze bewogen dus van links naar rechts in Tabel 1. Alleen nieuwe toetreders die profiteerden van de regelgeving hanteerden een progressieve politieke beïnvloedingsstrategie. Een andere belangrijke bijdrage van dit hoofdstuk ligt in de integratie van de literatuur over innovatiestrategieën en politieke beïnvloedingsstrategieën, om daarmee een alomvattend conceptueel raamwerk te creëren van de responsstrategieën van gevestigde bedrijven ten opzichte van beleidsinterventies die duurzaamheidstransities ondersteunen.

Tabel 1: Strategische reacties van bedrijven ten opzichte van technologieforcerend beleid

<table>
<tr><td colspan="2"></td><td colspan="5">Waardeperspectief</td></tr>
<tr><td colspan="2"></td><td colspan="2">Waardebehoud</td><td colspan="3">Waardecreatie</td></tr>
<tr><td rowspan="4">Strategische oriëntatie</td><td>Innovatie (naleven beleid)</td><td colspan="2">Reactieve innovatie strategie
Kosten-efficient voldoen aan technologie-forcerend beleid middels achterblijver innovatiestrategieën.</td><td colspan="3">Anticiperende innovatie strategie
Anticiperen op sterkere technologie-forcerende standaarden en beleidsverandering voor blijven door middel van pioniers en 'vroege volger' innovatiestrategieën.</td></tr>
<tr><td colspan="6">Algemene richting van strategische verandering →</td></tr>
<tr><td rowspan="2">Politieke beïnvloeding</td><td colspan="2">Defensieve strategieën:</td><td colspan="3">Proactieve strategieën:</td></tr>
<tr><td>Oppositie
Verzetten tegen beleid om de bestaande technologie te beschermen</td><td>Vertragen
Beleid vertragen en/of verlichten om naleving te faciliteren</td><td>Vormen
Het beleid vorm geven ten behoeve van innovatie strategie</td><td>Ondersteunen
Het beleid ondersteunen omdat rivalen hogere nalevings-kosten hebben</td><td>Progressief
De standaard van het beleid verhogen om de nalevings-kosten van rivalen te verhogen</td></tr>
</table>

Dit proefschrift leidt tot de conclusie, althans voor gevestigde autofabrikanten die de auto-industrie domineren, dat gevestigde bedrijven – middels hun innovatie- en politieke beïnvloedingsstrategieën – verschillende rollen spelen in duurzaamheidstransities. Deze gevestigde bedrijven vormden initieel een belemmerende factor voor een transitie, doordat zij verandering in de beleidsdimensie van het regime tegenwerkten en niet of marginaal aan de veranderende technologische component bijdroegen. Uiteindelijk vormden zij echter een belangrijke drijfveer voor transitie, door veranderingen in de technologische- en beleidsdimensies van het regime te ondersteunen. De verschuiving van bottleneck naar drijfveer voor transitie werd veroorzaakt door een strategische verschuiving op bedrijfsniveau, mede ingegeven door technologische concurrentie. Gevestigde bedrijven ontwikkelden verschillende technologieën, waardoor hun belangen steeds verder uiteen liepen. Gevestigde bedrijven met de prikkel en de kans om radicaal te innoveren waren de eerste die door middel van commercialisering van radicale duurzame automobieltechnologieën een duurzame transitie van het auto-transport systeem ondersteunden. De uiteenlopende belangen leidden niet alleen tot concurrentie in de technologische dimensie van het regime, maar ook in de beleidsdimensie – waar bedrijven streden om beleidsinterventies te vormen op manieren die gunstig waren voor hun eigen innovatiestrategie en/of ongunstig waren voor de innovatiestrategieën van hun rivalen.

Verder onderzoek zou moeten testen in hoeverre de bevindingen van deze explorative case studie over de innovatie- en politieke beïnvloedingsstrategieën van gevestigde bedrijven naar andere beleidsinterventies binnen de autosector en naar andere sectoren generaliseerbaar zijn. Bovendien is dit proefschrift alleen gericht op de strategische reacties van gevestigde bedrijven op veranderingen in de technologische- en beleidscomponenten van het regime. Het zou interessant zijn om te onderzoeken of bedrijven vergelijkbare reacties laten zien wanneer zij geconfronteerd worden met veranderingen in de wetenschappelijke, culturele, markt- of industriedimensies van het regime.

Om met het verzet van de industrie tegen beleidsinterventies om te gaan, bevelen we beleidsmakers aan om 1) hun interactie met de industrie zo veel mogelijk te richten op de individuele bedrijven in plaats van op de brancheorganisaties, 2) beleid te ontwikkelen dat concurrentie tussen bedrijven stimuleert om zo een gesloten industriefront van verzet open te breken, en 3) om technologie-forcerend beleid met vraag-stimulerend beleid aan te vullen. Vraag-stimulerend beleid ondersteunt ook de minder rendabele gevestigde bedrijven in hun risicovolle strategieën gericht op radicale innovatie, hetgeen hun kans op falen – en daarmee de kans op economische schade – vermindert.

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Appendix I Steps used to construct the search queries

It is complicated to construct good search queries. For example, there are studies using search queries like 'battery AND electric AND vehicle' for EVs. Such queries yield patents that can relate to any type of vehicle that uses batteries, which generate electric current. Hence, there will be a lot of irrelevant patents, or 'noise' that reduces the validity of studies employing ill constructed search queries. To construct more valid search queries we apply some rules of thumb extracted from previous studies (Oltra and Saint Jean, 2009; Frenken et al., Van den Hoed, 2005) as well as ones derived by ourselves.

1. First, our search queries focus on words in the 'title and abstract' field instead of on patent classes. We did not apply patent classes for two reasons. First, patent classes do not always specify the vehicular application of the class, causing them to yield irrelevant patents. For example, Pilkington and Dyerson (2006), using a patent class search on EVs, found that only 36% of their patents specified the correct (road) vehicular application. Second, CVTs incorporate many 'sub-technologies' that all need to be captured. In addition, "emerging technologies not clearly provided for in any one class may develop in more than one class simultaneously" (USPTO, 2012, p.6). Hence, the different CVT sub-technologies are captured by different patent classes, making it complicated to identify all of the numerous relevant patent classes within the continuously growing pool of over 70,000 existing patent classes. Finally, we prefer searching in the patent text itself over a derivative of it (patent classes), which are not constructed for our type of analyses but for the purpose of archiving patents. The use of key words allows us to specify vehicular applications and search for both the type of CVT and its different components.

2. Second, when searching for a specific CVT type or component, we use search terms to exclude patents belonging to other CVTs and related components, as is done by previous patent studies (Frenken et al., Van den Hoed, 2005). However, these studies excluded only HEVs and HFCVs, whereas we also systematically exclude EVs and ICEVs and their related components.

3. Third, with respect to the patent applicant field, we control for Asian inventors and Japanese Keiretsu-firms that commonly carry the same name as an automotive manufacturer, by specifically searching for the automotive manufacturer by using for example 'Mitsubishi' – two words separated from – 'Motor'.

4. Fourth, in order to make sure that the patents we find are relevant and not counted double in the database, for example because the initial attempt to gain a patent grant failed, we use a 'publication level filter'. We do not make use of a 'patent family filter', because as Oltra and Saint Jean (2009) stress, the fact that the same invention might be patented in different countries is an indication of its strategic importance, and hence its importance to technological development, which justifies its overweighting in our analysis.

5. Fifth, after applying the 'publication level filter' we use the Global Patent Index program's function to order the acquired data on the basis of the 'date of filing', which refers to the date the applicant filed for the patent. Using the date of filing in this successive step adds to the precision of the analysis as it reduces the time-lag with the moment of invention, i.e. the moment at which technological development actually took place.

The following combination of terms represents part of the conventional search query that was used to identify EV patents. Time and applicant were left out.

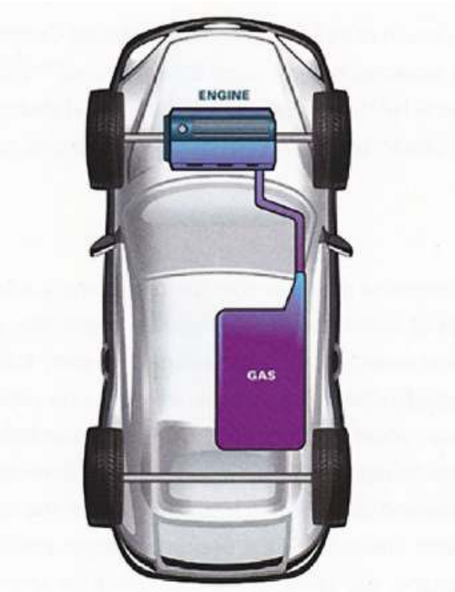
WORD = (electric* +2W (vehicle OR car OR automobile) OR battery +2W (vehicle OR car OR automobile)) ANDNOT (hybrid OR "fuel cell" OR "fuel cells" OR "internal combustion engine" OR hydrogen OR H2 OR "electric car window" OR "electric car wire" or ((train or trains) ANDNOT (powertrain or powertrains)) or locomotive or "power line")

Appendix II Technical explanation of powertrains

Figure A visually displays the powertrain configurations of different clean vehicle technologies (CVTs).

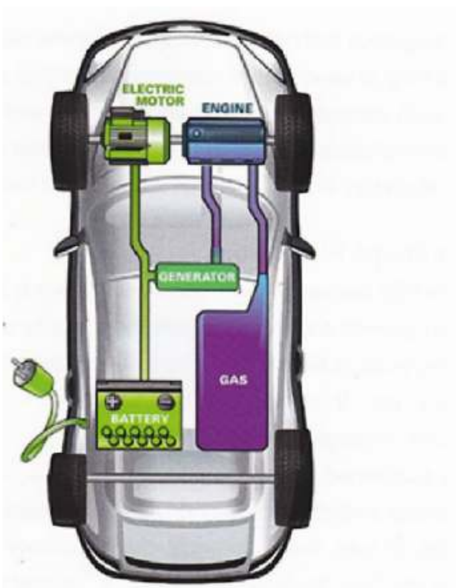
- *ICEVs*: Figure A.1 shows that in an internal combustion engine vehicle (ICEV) the wheels are directly driven by an internal combustion engine fuelled by a gasoline tank.
- *HEVs*: Figure A.2 shows that a hybrid electric vehicle (HEV) is driven by both a gasoline fuelled internal combustion engine and a battery-powered electric motor. This parallel configuration relies mainly on the engine as the battery can only be charged through regenerative braking. In a mild-HEV the battery enables only extra power, whereas full-HEVs can also drive in all-electric mode.
- *PHEVs*: The plug-in hybrid electric vehicle (PHEV) is a HEV that can charge its battery externally, from the electricity grid. Moreover, it may have a series, a parallel or a combined hybrid layout. As indicated in Figure A.3, a combined PHEV has a power-split that enables the engine to both drive the wheels directly as well as power the generator to generate electricity for battery storage. The Toyota Prius Plug-in is an example of a combined PHEV. The series PHEV depicted in Figure A.4 is also referred to as a range-extended electric vehicle, as wheels are driven directly by the battery-powered electric motor. The gasoline-fuelled engine powers a generator that can drive the electric motor or charge the battery to store electricity. Examples of series PHEVs include the Chevrolet Volt and BMW I3.
- *EVs*: Finally, the full-electric vehicle has zero emissions at the tailpipe as it can only drive electrically. As indicated by Figure A.5, the EV's powertrain has the most simplistic configuration with the battery providing the only source of energy. Neighborhood electric vehicles are, technically, low-speed EVs.
- *HFCV*: The hydrogen fuel cell vehicle also has zero emissions as its main fuel – hydrogen – has only water as a byproduct. The hydrogen fuels a fuel cell that generates electricity which can directly drive the electric motor, but can also be used to charge the battery – see Figure A.6.

Figure A, Visual presentation of ICEV, HEV, EV and PHEV powertrains. (Adjusted from: Plugin, 2014)

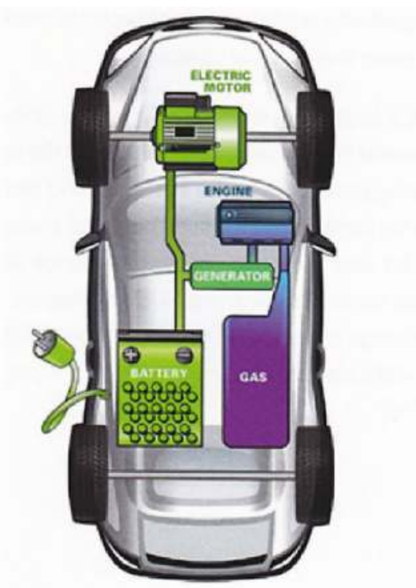


A.1: internal combustion engine vehicle (ICEV)

A.2: hybrid electric vehicle (HEV)



A.3: Combined plug-in hybrid electric vehicle (PHEV)



A.4: Series plug-in hybrid electric vehicle (PHEV or EREV)

A.5: Full-electric vehicle (EV)

A.6: Hydrogen fuel cell vehicle (HFCV)

A
Appendix

Appendix III List of abbreviations

This Appendix section lists the abbreviations used in this dissertation and, where necessary, discusses the way they are interpreted under the ZEV mandate. For a technical description of the powertrains of abbreviated clean vehicle technologies we refer to 'Appendix II - Technical explanation of powertrains'.

Table A, overview of acronyms, based on CARB (2012, p.2-3) and CARB (2000)

AAM	Alliance of Automobile Manufacturers
AIR	Air Improvement Resource Inc.
EV	Full-battery-electric vehicle
BEVx	A category in the ZEV-mandate for PHEVs where the engine is only used as a generator to power a battery that drives the wheels (i.e. a range extended battery electric vehicle) with an all-electric range of at least 75 miles.
CARB	California Air Resources Board
CVT	Clean vehicle technologies refer to both Low Emission Vehicles (LEVs) and Zero Emission Vehicles (ZEVs)
CPA	Corporate political activity
EPA	United States Environmental Protection Agency
GM	General Motors
HEV	Hybrid electric vehicle
HFCV	Hydrogen fuel cell electric vehicle
IVM	Intermediate volume manufacturer
LEV	Low emission vehicles are cars that emit less at the tailpipe, like HEVs and PHEVs.
LVM	Large volume manufacturer
NEV	Neighborhood electric vehicles are low speed EVs that, even though subject to different crash test requirements, qualify as passenger cars under California law.
PHEV	Plug-in hybrid electric vehicle. Except for the ZEV-category BEVx, in this dissertation we do not distinguish between PHEVs where the internal combustion engine directly drives the wheels and PHEVs where the engine is only used as a generator to power a battery that drives the wheels (sometimes referred to as extended range electric vehicles), because there are no credit categories in the ZEV mandate that differentiate on this aspect solely.
RBV	Resource based view
RDT	Resource dependence theory
ZEV	Zero emission vehicles are vehicles that have zero emission at the tailpipe, like EVs and HFCVs. When driven only electrically PHEVs could have zero emissions as well, however, Ford's PHEVs are driven approximately 60% of the time in full electric mode (Green Car Congress, 2013), which is why they are not included in the ZEV category.

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erg mooi de academische bevlogenheid in de sportzaal terug te zien! Allard (because geeks can be stylish too), Frank (the mathemagician aka ‘wizard of statistics’) en Kevin (+1/+1), samen hebben we de afgelopen jaren ook buiten werktijd hard gewerkt aan het waarmaken van het stereotype academicus, ik denk dat dit aardig is gelukt! Ik wil verder alle mede-promovendi bedanken voor hun gezelligheid en het samen doorstaan van onze ‘PhD struggles’, niet alleen de promovendi van de ‘10de’, maar die van de 9de en 11de natuurlijk ook.

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Joeri Wesseling

Utrecht, November 2014

Curriculum Vitae

Joeri Wesseling was born in Haarlem, The Netherlands, on October 26th 1986. In 2005 he completed his secondary education at the Sancta Lyceum in Haarlem. Interested in innovation, he then moved to Utrecht, to attend the interdisciplinary bachelor program 'Science and Innovation Management' at Utrecht University. Upon finishing this bachelor in 2008, he continued a 2-year research master in the same field. To complete his master program, Joeri did a 9-month internship at Deltares, where he wrote his master's thesis on the functioning of innovation systems around large infrastructural tenders in the Dutch water construction sector. He graduated in 2010.

From 2010-2014, Joeri worked on his PhD research project at the Innovation Studies group at Utrecht University. Aside from doing research, Joeri assisted in teaching innovation related courses. As part of his PhD project he also worked three months as a visiting scholar at the Institute of Transportation Studies at UC Davis, California. As a member of the Utrecht Geo Graduates PhD council, Joeri represented the interests of the PhDs of the Geosciences faculty.

List of publications

Wesseling JH, Faber J, Hekkert MP. 2014. How competitive forces sustain electric vehicle development. *Technological Forecasting and Social Change* 81, 154-164.

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