ABSTRACT

Title of Document:	INSTITUTIONAL LOGICS, COLLECTIVE ACTIONS AND DEVELOPMENT OF NEW TECHNOLOGIES
	Byungchae Jin, Doctor of Philosophy, 2011
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Technology development is an outcome of collective social processes among actors in different institutional fields. In the literature on technology development, there have been long debates regarding whether technology shapes social structure and order, or whether social forces determine the developmental trajectories of technology. From a series of studies, I seek to understand the social dynamics of technology development in order to address theoretical tensions, both theoretically and empirically. Three separate yet related studies together provide a theoretical model and relevant empirical evidence for the linkages among actors, institutional logics and technologies.

In Chapter 1 I first attempt to theorize about how actors, including scientists, engineers and technology users, collectively shape technological evolution in the general technology context. Combining the two perspectives—institutional logics and collective actions, I develop a theoretical model that addresses how scientists and

engineers, faced with multiple institutional logics, strategically respond to the multiple institutional logics, and how the different formation of institutional logics can systematically lead to different types of technology development. In the theoretical model, I discuss four distinctive social mechanisms of framing institutional logics—*replacing*, *patching*, *sequencing*, and *reinforcing*, and the relationships between the social mechanisms and the types of technology development.

In Chapter 2, building upon the theoretical model proposed in Chapter 1, I empirically investigate the emergence and decline of electric and hybrid drives in the community of electric vehicle researchers from 1969-2009. Combining the perspectives of institutional logics and social movements, I argue that an institutional logic is a product of collective social processes among actors in different institutional fields, and that established logics play an integral role in shaping the differential development of new technology. Empirical findings suggest that environmental protests and economic recessions systematically influence technologists' incorporation of two institutional logics (environmentalism vs. industrialism), and that social cohesion among actors within each institutional logic tends to shape differential developmental trajectories of electric and hybrid drives in the community of electric vehicle researchers.

In Chapter 3 I further explore the process through which actors respond to multiple and conflicting institutional logics, suggesting that actors can purposefully create new concepts and meanings, modify meanings of institutional logics, or reinforce existing meanings. While existing institutional work has suggested and

empirically demonstrated that institutional logics shape cognitive and behavioral patterns of actors, it still remains unanswered as to how actors can mobilize existing and new logics—differential decoupling processes. To trace the processes of constructing meanings of institutional logics, I conducted an inductive study by employing keyword-based, computer-aided text analysis of research proceedings published by the international *Electric Vehicle Symposium* in 1969 and in 1994. From the analysis, I identify four social mechanisms of logic construction: *clarifying*, *patching*, *expanding* and *reinforcing*. Moreover, empirical findings suggest that social mechanisms of *patching*, *expanding* and *reinforcing* are closely related to the emergence of hybrid drive.

INSTITUTIONAL LOGICS, COLLECTIVE ACTIONS AND DEVELOPMENT OF NEW TECHNOLOGIES

By

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2011

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Dedication

To my parents and family

Acknowledgements

Completion of this dissertation resulted neither from a one-day effort nor solely from my own capabilities. There have been interesting intellectual debates, lengthy interactive conversations and constructive feedback, all of which helped elaborate my arguments and enrich the rigor of these studies. Here I would like to sincerely thank those who have contributed to this work. In addition to those who directly impacted the dissertation, I would also like to thank the many people who encouraged me to successfully pass through this intellectually challenging doctoral program at the University of Maryland.

First, I would like to thank my dissertation advisor David Kirsch, who has been my mentor and friend throughout the entire doctoral program. When I was a first-year student, David presented an interesting research project about a historian's view of a local law firm's failure, which was something different and unique that I wanted to know more about. Ever since, we have met almost every week and have discussed tons of interesting topics ranging from 19th century U.S. society to the history of the Washington Nationals. Moreover, I might have been lost without his intellectual and personal support and help during the doctoral program. He challenged me to think about fundamental questions while emphasizing practical interests of social phenomena. In addition to personal interactions with him, I truly enjoyed his doctoral seminar "Organizational History and Theory" which aroused my intellectual curiosity with the joy of reading wise men's classics. All these valuable experiences helped me to conduct interesting, meaningful and rigorous research, and to formulate my own academic standards. I will never forget this precious opportunity. Lastly, from the instrumental perspective, without his help and support for collecting data, this dissertation would never have been completed. I am sincerely grateful for his help and support throughout the entire doctoral program.

I am also greatly indebted to my other committee members for helping me to successfully complete this dissertation. Ben Hallen provided interesting theoretical insights, and helped me to think through the theoretical aspects of this work. Whenever I ran into problems, Ben generously agreed to meet with me and helped clarify theoretical gaps in the literature. His valuable feedback is greatly appreciated. Alan Neustadtl graciously agreed to join my committee and helped elaborate theoretical arguments and pushed me to think through fundamental issues in social science. His priceless sociological insights significantly enriched this dissertation. Wes Sine helped me to consider fundamental and promising issues in the current institutional literature and to refine my theoretical arguments. His intuitions and insights helped me to understand the foundations of organization theory, thereby substantially improving this dissertation. In particular, he encouraged me to think through the gaps between perspectives of institutional logics and social movements and provided valuable feedback for me. Dave Waguespack helped me to conduct a rigorous and conclusive empirical study. During my doctoral coursework, I took his doctoral seminar “Methodology in Strategic Management.” In class, he always pushed students to think carefully about whether we can infer a true causality from empirical results and how effectively we can design a rigorous empirical study—all of which have undoubtedly helped me to conduct empirical research, including the research for this dissertation. I greatly appreciate his advice and support.

Besides my dissertation committee members, I am grateful to professors Mark Kennedy, Seok-Woo Kwon, Michael Lounsbury, and Robert Salomon for their invaluable comments on the early draft of this dissertation. In addition, I would like to express my gratitude to people in the PhD office, especially Ms. Justina Blanco, who generously helped me organize meetings for dissertation defense and submit my dissertation in a timely manner.

Without the data, I would not have been able to complete these studies. I would like to express my appreciation for the late Victor Wouk, and my thanks to Ms. Phoebe Ayers (University of California, Davis), Dr. C. C. Chan (University of Hong Kong), and Dr. Suk Won Cha (Seoul National University) for graciously sharing with me some of their own collections of research proceedings published by the international *Electric Vehicle Symposium*. I would also like to thank Michael Carter, Girish Chaskar, Wen Fei, Logan Miller, Haley Nalley, Adam Rhodes, Paige Santillo and Justin Shugarman for their research assistance for data coding.

Thinking beyond my dissertation, I cannot help thanking my doctoral colleagues: Azi Gera, Lori Kiyatkin, Dave Major, Scott Livengood, Lei Zhang, Daniel Malter, Vivian Wei Guo, Qiang Li, Annie Zavyalova, Bryan Stroube and Robert Vesco. They are my true friends and intellectual peers. In particular, I would like to give my special thanks to some of my doctoral colleagues. Azi has been my true friend and mentor since I have arrived at Maryland. I still remember the taste of burgers he made for us. Lori, as my formal student mentor, helped and advised me to successfully pass through coursework. Daniel and I began our doctoral programs in the same year. In particular, I would like to give him special thanks for introducing me to German cars and beer. Annie, Bryan, Robert, Qiang and Vivian graciously took notes for me whenever I presented this work.

I would also like to thank professors Kyungmook Lee, Dongok Cha, Jongtae Choi, Gyudae Hwang, Sunhae Hyun, Shikhyun Kim, Sungsoo Kim, Osoo Park, Won-Woo Park, and Youkeun Shin, who all helped me build theoretical foundations of Management and Organization.

Finally, I cannot close this acknowledgement without mentioning my parents and family who have always supported me throughout my entire life and created *Storge* in my family. Whenever I am weary of constant battle in my life, they always become my energy. Without their endless support, I would not have successfully finished this journey. In particular, I would like to thank my father, Hoiguen Jin who has been the compass of my life, and my mother, Gyunghee Han who has taught me what endless love means. I would also like to express my special thanks to my brother, Byungik Jin, and my sisters, Hyungsook Jin, Hyungshim Jin and Hyungran Jin for being always supportive throughout my life. I thus dedicate this dissertation to my parents and family.

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Chapter 1: Formation of Institutional Logics and Its Influence on New Technology Development

> *The consensus prevailing in modern science is certainly remarkable. Consider the fact that each scientist follows his own personal judgement for believing any particular claim of science and each is responsible for finding a problem and pursuing it in his own way; and that each again verifies and propounds his own results according to his personal judgement. Consider moreover that discovery is constantly at work, profoundly remoulding science in each generation. And yet in spite of such extreme individualism acting in so many widely disparate branches, and in spite of the general flux in which they are all involved, we see scientists continuing to agree on most points of science. Even though controversy never ceases among them, there is hardly a question on which they do not agree after a few years discussion (Michael Polanyi 1946, pp. 50-51)*

Technology development is an outcome of collective activities among actors. In this chapter I discuss how actors—including scientists, engineers and technology users—collectively shape technological evolution. Borrowing from and combining the two theoretical lenses—collective actions and institutional logics, I develop a theoretical model that addresses how actors in the technological and sociocultural spheres collectively shape the formation of institutional logics, and how the different formation of institutional logics can systematically determine the types of technology development. One of the critical contributions of this study is that I bring actors and institutions back into the discussion of technology development. I discuss theoretical linkages from actors, via logic formation, to technology development. Another contribution of this study is that it bridges a gap between technological and institutional approaches. To do this, I explore the social dynamics between technological and sociocultural spheres and theorize about how the two distinctive spheres simultaneously influence technological evolution. Finally, this study enriches current institutional arguments by showing how embedded agents collectively influence institutions, and at the same time are influenced by those institutions. This discussion will help us to better understand the dynamics of both institutional and technological changes.

1. 1. Introduction

The emergence of new technologies has been a topic of considerable interest to scholars from various disciplines, including sociology, economics and organization theory. The prevailing technology literature, in depicting the phenomenon of technological evolution, has centered on the roles of standardization (e.g., Farrell and Saloner 1985; Tassey 2000), on network externalities (e.g., Katz and Shapiro 1986; Khazam and Mowery 1994) and on technology life cycle (e.g., Anderson and Tushman 1990; Murmann and Frenken 2006; Suarez 2004). Economic models of technological development, for example, largely center on actors' rational assessments of the benefits and costs of developing or adopting new technology, techno-economic attributes of technology leading to technological innovation, and the diffusion of new technology (see Roberts 2008 for a review). The underlying assumption of these models is that human agents pursue technical rationality and purposefully maximize economic efficiency, thereby suggesting that technological development is an outcome of actors' rational choices.

In contrast, the institutional perspective casts doubt on actors' rational decision-making (Knight 1992; Meyer and Rowan 1977; Scott 1995). Rather, the institutional perspective accentuates cognitive limitations of actors when the actors attempt to assess the value of technology, and suggests that actors' choices of technologies are largely confined by institutional constraints that shape cognitive and behavioral patterns of embedded actors (e.g., DiMaggio and Powell 1983; Strang and Soule 1998). The bounded rationality assumption of actors explains the reliance of actors on rules and principles that are socially and culturally proven to achieve technical rationality (Meyer and Rowan 1977). More recently, technology scholars have applied this perspective to gain an understanding of how broader institutions and institutional framework influence technology development (see Kaplan and Tripsas 2008, for a review).

While these two perspectives represent agency-based and structural views of technology, they both tend to overlook endogenous social and cultural processes which are often outside rational decision-making and also influence the trajectories of new technological development (e.g., Barley 1986; MacKenzie 1987; Orlikowski 1992). Although a handful of research on strategic action discusses the positive role of actors' strategic intention in shaping technical and institutional environments (DiMaggio 1988; Fligstein and McAdam 2011; Oliver 1991; Suchman 1995), theoretical development and subsequent empirical findings are as yet limited.

The social constructivist view of technology, on the other hand, intimates that the development of technology is a product of actors' collective interpretations of technology and focuses on the roles of cognitive/cultural interpretations of actors and collective activities in technology evolution (e.g., Callon 1987; Pinch and Bijker 1984). This view seeks to address collective social and cultural processes through which a particular technology emerges as a dominant design in the technology field. Subsequent empirical studies provide rich contextual descriptions of collective social processes associated with technology development (e.g., Grodal 2010; Kaplan and Murray 2010; O'Mahony and Bechky 2008). Although these studies help us better understand the social and cultural processes through which actors make sense of the meaning of new technology, this view has not yet addressed how social actors actively frame the interpretations of technology and how these framing processes influence technology development (See Kaplan and Murray 2010 for an exception).

Moreover, much empirical work is confined to case studies or document analyses which inherently limit casual inferences. Particularly in the technology field where technologists constantly introduce a number of new technologies and enhance or destroy the existing technologies, the technologists inevitably encounter a lack of a consensus of the meaning and value of new technologies (Grodal 2010). It is therefore important to understand the social processes through which technologists develop shared understandings of new technology and determine future developmental trajectories of new technology.

Technology development is indeed a cognitive and cultural process of destroying prevailing understandings of old technology and providing new concepts of technology. In considering the complex and dynamic features of technology evolution, a fundamental question still remains unanswered and debated: How do institutions and actors collectively contribute to the emergence of new technology?

In order to better understand the complexity and dynamics of such a social phenomenon, research on technology should focus on the holistic aspect of technology development rather than on certain features of it. While early research into technology and entrepreneurship offers insights into how technological development can be a function of entrepreneurial actions and of the society's stores of knowledge (e.g., Kirzner 1973; Romer 1990; Rosenberg 1982; Schumpeter 1934), endogenous processes of creating new scientific knowledge and technology remain largely under-theorized in the current studies of technology and entrepreneurship. Furthermore, there have been few theoretical and empirical efforts directed at exploring the collective social and cultural processes among actors who can potentially determine the trajectories of technology development. As a result, not enough is known regarding *why* some technologies survive and gain legitimacy but others do not; *how* entrepreneurial actors collectively shape and manage the disparate nature of technologies; and *how* actors' collective beliefs—institutional logics (I will define this term in the later section)—systematically influence the technological choices of actors, both theoretically and empirically.

Borrowing from theories of collective actions and institutional logics, in this chapter I therefore seek to provide a theoretical framework which accounts for (1) how technologists collectively frame multiple institutional logics in the technological community, and (2) how institutional logics associated with technologies can play an enabling or disabling role in technology development. With the theoretical model proposed in this study, I reintroduce and theorize about the middle-range social processes influencing the evolution of new technologies in the technology context.

Ultimately, the model addresses why new technologies follow different developmental trajectories.

1. 2. Technology, Institutions and Institutional Logic

1. 2. 1. Technology

Research on technology generally views technology as human production activities by which actors transform physical inputs into desired outputs (e.g., Hulin and Roznowski 1985; Thompson 1967). The concept of technology proposed by technology scholars is not necessarily limited to physical equipment, machines, tools, and instruments used in human production activities. The concept encompasses work processes, tasks, methods, skills and knowledge through which actors efficiently produce and reproduce desired outcomes (Perrow 1967; Schiffer 2001; Thompson 1967).

The technology literature has long discussed the origins and consequences of technological development. One line of technology studies has explored the endogenous processes of technological development, largely focusing on organizational and macro-economic factors that drive technological development (e.g., Romer 1990; Rosenberg 1976, 1982; Scherer 1965). It is now well-documented that R&D inputs, marketing efforts and administrative capabilities play integral roles in driving technological innovation and organizational growth (for a review see Cohen and Levin 1989). The economic models of technology primarily suggest that stocks of knowledge of organizations are crucial for technological development, and emphasize that the efficient allocation of stocks of knowledge is crucial to driving technological innovation (Romer 1990; Scherer 1967). The primary goal of the economic models is to identify antecedents potentially influencing technological innovation, and to estimate the relative impacts of the antecedents on innovative outcomes. Thus, the economic models still tend to treat scientific knowledge or technology as exogenously given, and thereby remain silent about the origins of knowledge or technology (Rosenberg 1982).

Another line of studies on technology, led by the unique properties of technology in the organizational context, has examined structural outcomes (Galbraith 1977; Perrow 1967; Woodward 1965). In particular, early organizational theorists have noted that technological attributes—such as technical complexity, uncertainty and interdependence—are closely associated with levels of formalization and centralization of organizational structures (e.g., Thompson 1967). The empirical evidence that was discovered led them to conclude that technology constrains human activities and determines features of work processes and organizational structures (Perrow 1967; Thompson 1967; Woodward 1965). This insight has motivated a great number of subsequent empirical studies in which researchers continue to confirm a causal linkage between technology and organizational structure (e.g., Carter 1984; Harvey 1968). This stream of technology research has echoed technology determinism: technology shapes social structure and order.

Therefore, despite the extensive work on the antecedents and consequences of technology, neither stream of research appropriately accounts for the origins of scientific knowledge known to serve as a major source of technological innovation—or how new scientific knowledge is developed. Based on the critique of the rational system view of technology and technology determinism, a body of scholars contends that technology is indeed socially constructed (e.g., Callon 1987; Davis and Taylor 1976; Hughes 1987; Pinch and Bijker 1984). They argue that technology is a product of social and political negotiations of actors (e.g., Pinch 1996). This social constructivist view of technology, rooted in the sociology of knowledge (Berger and Luckmann 1967; Foucault 1980; Mannheim 1936), has shifted the discussion of technological development from objective to subjective views of technology (e.g., Law 2000). Departing from the pursuit of exploring absolute truth, this subjective view of technology focuses on the social and cultural processes of producing scientific knowledge (Latour 1987). The tenet of the subjective view of technology is that scientific findings are indeed open to more than one interpretation. Thus, fundamental to this approach is how scientists and engineers with different interpretations deal with disagreements on scientific findings.

Pinch and Bijker (1987), for example, accentuate the role of a set of relevant social groups, each of which shares the same interpretative schemes about a certain artifact or technology. They extended the subjective view of technology by incorporating the Empirical Programme of Relativism (EPOR) approach into the extant sociology of science and technology. Consistent with the subjective view of technology, the EPOR approach assumes that there is no single interpretation of scientific findings. This assumption motivates the exploration of the social aspect of scientific development. Social actors within the same social group tend to develop similar identities, share a similar technological culture (i.e., technical hobby) and collectively guide the future development of technology (Haring 2007). According to the Pinch and Bijker (1987), differences in interpretative schemes across different social groups lead to controversies over technological problem-solving. Once social groups reach a consensus about the meanings of artifacts or at least *believe* potential problems associated with the artifacts to be solved, conflicts in the interpretations of the artifacts become stabilized, and technological controversies are resolved.

Unlike Pinch and Bijker's (1987) emphasis on the importance of social environments to problem-solving during the development of technology, Hughes (1987) views technology as a dynamic system that includes both technical and social environments where there are no social boundaries of disciplinary knowledge. He suggests that technological systems are comprised of all relevant components associated with technology—such as inventors, scientists, engineers, managers, financiers, workers and policymakers—and that these components are functionally interconnected. Similarly to Pinch and Bijker (1987), he regards technological development as a process that enables a system to achieve a new state of equilibrium. He however sees no clear distinction between technology and social domains; and he considers science, technology and the whole society to be tightly linked as a system. He argues that, consequently, the development of technology is not only driven by actors' social engagement but also by changes in certain components of a system or imbalance within a system.

Both Pinch and Bijker (1987) and Hughes (1987) implicitly concur that to be successful entrepreneurs, technology entrepreneurs who produce new scientific knowledge and technology should understand social values, culture and institutional constraints that constitute an integral part of a technological system (Carlson 1994).

Callon (1987) elaborates and extends the views of both Pinch and Bijker and Hughes regarding technology. He seeks to incorporate into technology studies an actor-networks argument. Like Hughes (1987), Callon (1987) also views actors as linked together within a seamless web. Heterogeneous actors are basic elements that constitute networks; and the networks include both human and nonhuman components. Actors share simple and common interpretations, and similar identity and mutual interests; and networks are the dynamic associations by which actors exchange information with other actors and continuously fill interpretive gaps among actors. This view of actor-networks describes the dynamics of interconnectedness within the whole society. The identity of actors and the mutual relationships among them are neither perfectly defined nor stable. Callon (1987, p. 93) argues that "an actor network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to redefine and transform what it is made of." Actors' associations are continuously redefined. New elements can at any moment be assimilated into networks, a process which shifts the nature of actors' identity.

In sum, the main contributions of the social constructivist view of technology are (1) that it extends the extant argument of technology largely couched in the technical environments to the social environments; and (2) that it attempts to open the "black box" of how technology and scientific knowledge are generated, interpreted and developed. Contributions notwithstanding, subsequent empirical studies have been limited due to the difficulties in developing analytical tools or methods (for a discussion see Pinch 1996; Klein and Kleinman 2002). More recently, some scholars argue that although the social constructivist view of technology contributes to the agency-based approach, it tends to overlook structural factors that can potentially play a central role in technological development (e.g., Klein and Kleinman 2002).

1. 2. 2. Theoretical Debates between Technical and Institutional Fields

Departing from the prevailing technology arguments, institutional theorists have long suggested the unique roles that institutions play in the technology context. Institutions are defined as supra-organizational patterns of practices which regulate behaviors of human agents (Friedland and Alford 1991; Hughes 1939; Jepperson 1991; Scott and Meyer 1983). In the early neo-institutional models, the distinction between "technical" and "institutional" has become a central research agenda; the former represents the efficiency logic; and the latter represents the legitimacy logic (e.g., DiMaggio and Powell 1983; Kraatz and Zajac 1996; Orrù, Biggart, and Hamilton 1991; Scott and Meyer 1983; Tolbert and Zucker 1983).

Neo-institutional theory proclaims that actors' rational behaviors stem from their intention to conform to social rules and rituals that they believe to be rational and legitimate (e.g., DiMaggio and Powell 1983; Phillips and Zuckerman 2001). The theory is based on a criticism of the traditional technical rationality argument which seeks to address organization-environment relationships, mainly in the context of technical environments. Neo-institutional theory puts more emphasis on institutional environments than on technical ones. DiMaggio and Powell (1983) note that in the early twentieth century, the bureaucratization and rationalization of organizational structures was developed as a means of efficient control of social actors. They view highly rationalized structures as resulting from market competition across firms and states. However, they raise a fundamental question: Why do bureaucratization and rationalization still occur, even without achieving any further efficiency? Challenging the notion of technical rationality, they propose that today's bureaucratization may result not from the actors' pursuit of internal efficiency but from institutional processes affected by the professions and the state. Echoing DiMaggio and Powell (1983), Scott and Meyer (1983) have also discussed the unique roles of institutional environments as distinct from technical environments. Within the technical environment, products and services are exchanged. The control mechanism in the technical environment is *efficiency*—whether actors can produce outputs in a more efficient way. In contrast, the institutional environment provides actors with rules and requirements to which they must conform. Thus, its control mechanism is *legitimacy*—whether actors receive support from the broader environment.

Led by this insight, early studies that draw upon neo-institutional theory, have primarily attempted to find distinctive roles of institutions in the organizational fields (Singh, Tucker, and House 1986; Tolbert and Zucker 1983; Westphal, Gulati, and Shortell 1997). For example, Tolbert and Zucker (1983) in their two-stage diffusion model demonstrate that organization-specific technical and economical motivations lead to the early adoption; whereas organizations' reliance on the benefits of legitimacy drives the later adoption. Similarly, Westphal, Gulati and Shortell (1997) reveal in their study of the adoption process of Total Quality Management (TQM) practices across hospitals that early adopters tend to customize TQM practices to local conditions in order to achieve efficiency gains; whereas late adopters adopt conventional forms of TQM. They further find that late adopters' conformity to convention increases legitimacy among hospitals but decreases their internal efficiency.

This two-stage diffusion model motivates a number of subsequent studies which investigate the effect of organizational heterogeneity on the diffusion of practices. The research, to date, has discovered that organizations' network positions (Greenwood and Suddaby 2006; Kraatz 1998), geographical locations (Lounsbury 2007) and social status (Kraatz 1998) influence their adoption of particular practices. Empirical findings strengthen the idea that technical and institutional environments exist independently, influencing actors' behaviors at the different diffusion stages.

However, more recently scholars contend that the two-stage diffusion model tends to overlook the reciprocal relationships between technical and institutional fields. They argue that technical environments may not be independent of institutional environments (Friedland and Alford 1991; Garud and Kumaraswamy 1995; Lounsbury 2007; Scott 2008; Thornton and Ocasio 2008). For example, Thornton (2004) argues that technical and market structures are the outcomes of actors' cognitive and cultural framing, and thus they are indeed embedded in institutions along with other social structures. Her argument implies that technologies, markets and profit organizations form a subset of institutions.

Further, Alford and Friedland (1985) emphasize that multiple practices and beliefs inherently exist in contemporary society. They assert that the bureaucratic state, families, democracy, capital markets and religion constitute major institutions in modern western society. They consider institutions to be material practices and symbolic systems in the society, which encompasses both technical and institutional environments (Friedland and Alford 1991). According to their notion of institutions, capital markets, known as a core of technical environments, constitute an important aspect of institutions in the modern western society. Even in their technology study, Garud and Kumaraswamy (1995, p. 227) claim that "[w]e can understand and better shape the evolution of technological systems by coupling their institutional and technical environments." They suggest that it is important to take into consideration the interconnectedness between technical and institutional environments in order to understand the complexity of technological evolution.

Mounting evidence also casts doubt on the schematic findings of the two-stage diffusion model. Palmer, Barber, Zhou, and Soysal (1995) have discovered that economic aspects have been quite important factors influencing the widespread diffusion of organizational forms and business practices, even in the later diffusion process. Moreover, Kennedy and Fiss (2009), in their empirical research on the diffusion of TQM among U.S. hospitals in the early 1990s, have also found that both motivations to gain social legitimacy and to improve economic performance co-exist throughout the entire diffusion process. Furthermore, in their study of the U.S. electricity industry, Sine, Haveman and Tolbert (2005) have shown that institutional conditions systematically influence the emergence of novel technology at the early stage of technology adoption. Sine et al. demonstrate that institutional-level regulative and cognitive support for novel but as yet unproven technology encourages entrepreneurs to adopt the novel technology and to subsequently build new electric-power plants using the novel technology. This evidence, taken together, challenges the findings of the two-stage diffusion model—efficiency purposes in the early stage, and legitimacy purposes in the later stage—implying rather that actors' consideration of technical rationality may be part of institutional processes.

The debates about the boundaries of technology and institutions expand into a discussion of the appropriateness of the definition of institutions. As mentioned earlier, institutions are generally defined as supra-organizational patterns of social practices which regulate actors' behaviors (Friedland and Alford 1991; Hughes 1939). Institutional scholars note that these patterns of practices are socially constructed, and they are regulated by a set of rewards and sanctions (Jepperson 1991). Further elaborating the concept of institutions, Scott (1995, 2001, 2008) proposes three pillars of institutions: the regulatory, normative and cognitive-cultural structures.

There is, however, a considerable debate regarding whether institutions should possess all three properties (see Phillips and Malhotra 2008, for a review). Phillips and Malhotra (2008) argue that while Scott's three pillars are fairly comprehensive, the integration of three pillars as one unity of institutions may be problematic. Because the three pillars of institutions are derived from different theoretical disciplines, each aspect of institutions involves different philosophical assumptions about social reality and thereby asks different fundamental questions. For example, Meyer and Rowan (1977) primarily emphasize the cognitive and normative aspects of institutions. They argue that institutions ". . . inevitably involve normative obligations but often enter into social life primarily as facts which must be taken into account by [the] actor (Meyer and Rowan 1977, p. 341)." Based on this definition of institutions, they further define institutionalization as ". . . the processes by which social processes, obligations, or actualities come to take on a rule-like status in social thought and action. . .” which again includes only cognitive and normative processes. Berger, Berger and Kellner (1973), on the other hand, stress social actors’ cognitive thought-processing. They argue that social actors face different viewpoints of modernization, a situation which forces the social actors to isolate themselves from the meanings of modern institutions. North (1990) emphasizes the regulative aspect of institutions. He views institutions as the formal and informal “rules of the game” which enforce actors’ behaviors. Thus, according to North’s (1990) perspective, punishment for the violation of the rules is enacted to control actors’ behaviors.

In addition to the problems regarding the disparate nature of institutions, Hirsch (1997) further argues that Scott’s view of institutions tends to be static, because it fails to adequately address how actors respond to social conflicts about norms and values and how institutional change can take place if a violation of conformity to shared norms and values is penalized by a set of rewards and sanctions.

Notwithstanding the debate about the definition of institutions, recent institutional work implies that technology comprises a subset of institutions (Thornton and Ocasio 2008). Technology has unique characteristics of pure scientific knowledge—a property of *actuality*. At the same time, technology is socially constructed by scientists, engineers, policymakers, technology users and other relevant social groups—a property of *social process*. In other words, technology can be an institution that is made up of a set of actual production activities which have meanings and values for the society. Thus, it is evident that technology involves a cognitive and cultural aspect of institutions.

Additionally, in the previous section I defined technology as human activities believed to maximize economic efficiency and technical rationality. Thus, to some extent, technology involves a normative aspect of institutions—rules guiding human behaviors believed to maximize economic efficiency. Consequently, recent institutionalists tend to consider technology to be a subset of an institution, and technological development to be institutionalization processes through which actors develop shared meanings, norms and values associated with technology.

The primary purpose of this study is not to address this debate regarding whether technology is an institution. What is more important is how actors and institutions together shape technology development. Thus, this study explores social processes influencing the reciprocity among actors, institutions and technology. Related to the traditional structure-agency arguments, additional fundamental questions about the evolution of technology also include (1) whether institutions shape technology development, (2) whether human agents collectively determine the destiny of technological development, and/or (3) whether institutions shape actors' cognition and behaviors in the technology context (Orlikowski 1992).

While the relationships between institutions and social actors have long been discussed in the fields of organization theory and sociology, empirical findings are still incomplete and debated (e.g., Alexander and Giesen 1987; DiMaggio and Powell 1991; Giddens 1979, 1984; Scott 1995; Sewell 1992). Scholars based in neo-institutional theory generally emphasize the role of institutions in shaping social actors' behaviors and cognition (e.g., DiMaggio and Powell 1983; Meyer and Rowan 1977). Research drawing upon this theory views actors as socially, economically and politically embedded agents largely confined by institutional constraints. Resulting empirical studies have focused on several processes: isomorphic and diffusion processes of adopting formal structures and practices (e.g., Fligstein 1985; Tolbert and Zucker 1983), societal and cultural mindsets influencing organizational founding (Dacin 1997), effects of actors' collective mindsets on their homogeneous political behaviors (Neustadtl and Clawson 1988), and the differential effects of institutional logics on managerial attention (e.g., Thornton 2002; Thornton and Ocasio 1999).

In contrast, research based on institutionalization theory and rooted in the social constructivist view explores the process through which actors generate new institutions, understand their meanings, share new meanings with other actors, and in turn gain legitimacy (e.g., Berger and Luckmann 1967; Elsbach 1994; Suchman 1995). Research in this vein has identified the strategic actions by which actors develop new institutions and gain legitimacy (e.g., Fligstein 2001; Jarzabkowski 2008; Rao, Monin, and Durand 2003; Suddaby and Greenwood 2005). Mounting empirical evidence suggests that actors may not be passive agents who conform to institutional constraints, but rather purposefully evaluate the benefits and costs to adopting institutions, given their institutional constraints (e.g., Rao, Greve, and Davis 2001). Some scholars have found that economic crisis and new technological developments can become sources of institutional change (e.g., Barley 1986; Oliver 1992; Tolbert and Zucker 1983); and that actors' structural network positions and political dominance influence their ability to change institutions (Greenwood and Suddaby 2006; Tarrow 1998). Other scholars have discovered that in order to gain legitimacy for new institutions, actors use a variety of rhetorical strategies (e.g., Suddaby and Greenwood 2005), intentionally familiarize new institutions with old ones (Hargadon and Douglas 2001), and often compete for stakeholders' endorsements (Rao 1994).

Recent research on institutional theory has proposed bridging the two perspectives (Barley and Tolbert 1997; Klein and Kleinman 2002). In order to incorporate the two fundamentally different views, Barley and Tolbert (1997, p. 96) propose a modified definition of institutions: "shared rules and typifications that indentify categories of social actors and their appropriate activities or relationships." Given this modified definition of institutions, they specify that "institutions vary in their normative power and their effect on [human agents'] behavior (Barley and Tolbert 1997)." The variations of institutions in terms of their social standings, historical backgrounds and social influences allow room for actors to exert influence on the institutions. Institutions are no longer enduring or stable, but constantly constructed by the collective behaviors of social actors. In order to comprehend the mechanisms of institutional change, it is therefore important to understand how actors influence the construction of institutions—and at the same time how institutions shape the embedded actors' daily activities. The institutional logic approach, to some extent, addresses these dynamic institutional processes. I discuss this approach in greater detail in the following section.

1. 2. 3. Institutional Logic

A review of the extant technology and institutional literature suggests that the emergence of new technology is closely associated with the cognitive and cultural interpretive processes that occur among actors. Through the interactive processes, actors understand the meanings and socio-economic value of new technology. An important question that then arises is this: How is technology constructed by social actors? In order to better understand social processes shaping the emergence of new technology, I revisit the concept of institutional logic developed by institutional scholars, and I argue that institutional logics can play a mediating role in connecting actors to technology.

Institutional logics are defined as social actors' collective cognitive and cultural prescriptions that guide their interpretations of institutions and behaviors. Alford and Friedland (1985) initially coined the term *institutional logics*, claiming that an individual institution has a unique logic that regulates behaviors and cognition of social actors within the institutional field. Thornton and Ocasio (1999) extend Friedland and Alford's (1991) notion of institutional logics, and they augment the concept of institutional logics by adding the notion of social construction. They explicitly define institutional logics as the "socially constructed, historical patterns" of material practices and cognitive/cultural principles by which embedded social actors replicate their material substance and provide meaning to their society. This view suggests that institutional logics provide actors with rules, principles and cultural assumptions about how to interpret institutions and how to behave. Greenwood, Díaz, Li, and Lorente (2010) recently highlighted the temporal flexibility and multiplicity of institutional logics to better understand the role of institutional logics in institutional change. They therefore defined institutional logics as taken-for-granted “resilient” social prescriptions that enable actors to make sense of their situation (Greenwood, Díaz, Li, and Lorente 2010, p. 1).

The multiplicity of institutional logics within a single institutional environment implies that social actors can encounter events in which different institutional logics may collide with one another. The contestation between different sets of institutional logics can lead to social conflicts that require institutional logics to be more flexible, which is somewhat different from the neo-institutional arguments suggesting institutional lock-in after the legitimation process. The property of multiplicity suggests that institutionalization may not be a single process that smoothly converges on structural homogeneity in the long run. Rather institutionalization is a multiple and complex process through which social actors who are faced with competing institutional logics create social conflicts and actively support particular sets of logics. Even after the legitimation process, embedded social actors are indeed exposed to the potential conflict in logics. Locally institutionalized beliefs, norms and values may escalate social conflicts, because social actors with these localized institutional logics may not easily adopt other institutional logics.

In addition, Thornton and Ocasio’s (1999) notion of social construction makes it possible to address the dynamic process of constructing or deconstructing institutional logics, simultaneously leading to de-institutionalization or re-institutionalization processes (Oliver 1992). This temporal flexibility of institutional logics results from social actors’ collective processes of reaching a social consensus. Because technological evolution is a social and cultural phenomenon occurring at different temporal and analytical levels, it is important to understand how social groups embedded within their own institutional logics interact with other social groups with different institutional logics—and how they reach a social consensus of meanings of technology and collectively determine technological trajectories (e.g., Pinch and Bijker 1984).

1. 3. Theoretical Framework of Technology Development

1. 3. 1. Technology, Institutional Logic and Actor

As I discussed in the previous section, institutional logics provide actors with cognitive and material guidelines which actors use to interpret technology and embed it into their daily lives. Figure 1 portrays the relationships among actors, institutional logics and technologies. Actors are often faced with multiple institutional logics that are embedded within their own institutional logics. Due to the embeddedness, institutional logics can enable or disable actors to adopt a particular technology. As prevailing institutional logics arguments suggest, actors' interpretations are largely constrained by institutional logics (e.g., Friedland and Alford 1991; Thornton and Ocasio 1999). The interpretive flexibility of actors is a critical factor that influences the subsequent development of new technologies or further technological innovation (e.g., Bijker 1987; Kaplan and Tripsas 2008). The introduction of new technology triggers conflict between different institutional logics. Existing social actors attempt to make sense of the new technology, based on their own institutional logics.

*** Insert Figure 1 about here ***

In sum, institutional logics provide actors with cognitive or normative tools with which the actors can share the meanings of technology and support a certain technology. Technology development is thus tightly entangled with these cognitive and normative tools (Bijker 1987; Kaplan and Tripsas 2008).

1. 3. 2. Overview of Theoretical Framework

Competition among alternative technologies is the social process through which multiple and conflicting institutional logics in different institutional fields compete against one another. Thus, it is important to understand the reciprocity between technology-related fields associated with technology development. In the technology field, technology entrepreneurs introduce a new technology to their technology community, leading to technological innovation. The introduction of a new technology or practice spontaneously triggers discourse both within and outside the technology field (Phillips, Lawrence, and Hardy 2004). Actors in different institutional fields use different institutional logics to interpret a new technology (Garud and Rappa 1994). In the situation where multiple logics are equally significant and simultaneously affect the cognition and behaviors of actors, conflict in institutional logics may take place (Greenwood, Díaz, Li, and Lorente 2010). The successful management of contested institutional logics depends on how effectively technology entrepreneurs mobilize different logics and build social alignment across the logics (Garud, Hardy, and Maguire 2007; Munir and Phillips 2005).

On the other hand, actors in the sociocultural field can also influence technology development. Social movements theory in particular suggests that the collective actions of actors that occur in the social, political and economic spheres can shape logic-framing processes and can thus influence the outcomes of logic contestation (Benford and Snow 2000; Snow, Rochford, Worden, and Benford 1986). Actors who are dissatisfied with prevailing logics form a social group which shares similar beliefs, gradually developing a shared identity, and acting to change the current status quo (e.g., Tilly 1978). Through this process, actors collectively create a new institutional logic (Rao, Monin, and Durand, 2003). In particular, when social movements aim to solve generic social issues such as environmental protection, income gap, gender inequality and labor-related activity, an institutional logic resulting from these social movements can easily diffuse into different institutional fields (McAdam and Scott 2005). Through these collective processes, a new institutional logic that is created in the social and cultural field can influence technology development.

Figure 2 depicts the interplay between technology and sociocultural fields, which can determine the evolution of new technology. To explore the collective social and cultural processes of technology development, I first distinguish between technological and sociocultural fields where technology inventors and users exchange their own institutional logics associated with new technology. A new technology generated by technology entrepreneurs spontaneously triggers technological discourse and creates unequivocal and multiple interpretations of the new technology in the technology field. Through a series of professional debates, technologists mobilize new and old logics, develop shared understandings of the technology, and then reinforce the newly-created logic. If other technical groups do not accept the new logic, it will not develop into a taken-for-granted institution, and as a result the related technology will not survive.

*** Insert Figure 2 about here ***

Furthermore, a new institutional logic accepted in the technology field may not be able to develop into a socially and culturally shared institution until it is accepted in the sociocultural field. In this field technology users are critical players. They also create their own interpretations of a new technology. Based on their own logics, they evaluate the usefulness and value of the new technology in their daily lives. The institutional logics of technology users may consist of familiarity, utility and the socio-economic value of new technology. If the newly-developed logic is not well-aligned with the logics of technology users, again it will not be accepted as a taken-for-granted institution, and the related technology will not gain legitimacy. Institutional entrepreneurs are those who are capable of creating new social structures or roles, in turn shaping the logics of technology users (Garud, Hardy, and Maguire 2007; Garud, Jain, and Kumaraswamy 2002; Fligstein 2001).

On the other hand, actors in the sociocultural realm can influence technological discourse by directly introducing a new institutional logic to the technology community. Social movements that create abstract-level ideology or that target specific technologies often drive a fundamental change in the existing institutional logics in the technological field (Fligstein and McAdam 2011; O'Mahony and Bechky 2008).

Faced with multiple and competing institutional logics, technologists may choose different institutionalization mechanisms, depending on the extent of the need for supporting a new logic in the technology and sociocultural fields. I propose four distinctive institutionalization mechanisms which take place in the technology field.

A new logic may replace an existing logic—*replacing* (e.g., Thornton 2002), complement it—*patching* (e.g., Gylnn and Lounsbury 2005), temporally be used—*sequencing* (e.g., Hargadon and Douglas 2001), or resist accepting it—*reinforcing* (e.g., Oliver 1991). These four mechanisms determine four different types of technological development. In the following sections, I first discuss in greater detail the interplay between technological and sociocultural fields and then develop several propositions that theorize about linkages between formation of institutional logics and types of technology development.

1. 3. 3. Linkage between Technological and Sociocultural Fields

In the technology field, technology entrepreneurs—such as scientists, engineers, technical professionals and policymakers—collectively introduce new technologies and relevant practices, and share their meanings through a series of discussions. Technologists resonate with other technical groups and often modify their own technological frames. Subsequent development of technologies and relevant practices, and further elaboration of the concepts and meanings of technologies are largely constrained by the extent to which technology entrepreneurs with different knowledge repertoires are committed to their own technological "habitats" (Berger and Heath 2005; Bourdieu 1996; Camic 1986; Garud and Rappa 1994). This is because the strong commitment of technologists to their own technological frames often makes it difficult to understand or adopt new technological concepts (Bijker 1987; Carlile 2002; Dougherty 1992).

Bijker (1987), for example, stresses that the degree of the interpretive flexibility of scientists and engineers determines the success or failure of technological development. He argues that scientists or engineers with more flexible technological frames are better-equipped to recognize nuanced differences in knowledge and to assimilate the knowledge into their own frame. Echoing Bijker's (1987) notion of interpretive flexibility, Orlikowski (1992) demonstrates that actors with high levels of interpretive flexibility are the ones who perceive the limitations of the current technology and alter its functionality. Likewise, Carlile (2002) suggests that it is more important to develop common artifacts, standardized methods and formalized practices from which engineers and scientists embedded within their own technological frame can successfully cooperate to create new technology. Dougherty (1992) similarly argues that social groups from different knowledge domains would face interpretive barriers, because each technological domain has its unique "thought world" that helps its social group understand problems and issues in its own domain, but at the same time prevents its social group from understanding ideas from different knowledge domains. She further suggests that in order to manage these interpretive barriers, it is crucial to build formal structures that facilitate collaboration across disparate knowledge domains.

These mechanisms discussed above imply that logic construction consists of two primary components: representation of embedded actors' knowledge and social interactions among actors. That is, logic construction includes a set of actors' activities of integrating a variety of interpretations of novel technologies and relevant practices, and expanding local interpretations into community-level logics.

The representation of embedded actors' knowledge is the process through which social actors translate their own "thought world" into different "thought worlds". Of particular importance in the knowledge representation stage is choosing the proper words to alert the attention of the other actors, triggering technological discussions and enhancing collective memory. This is because representations are largely constrained by the knowledge repertoires of social actors. Beger and Heath (2005) introduce a concept of "habitat" and argue that an idea's success varies with the prevalence of its "habitat." Ideas are culturally embedded within the "habitat" which provides cues for helping to retrieve previous memory. The underlying argument is that an idea resides in a record and that the "habitat" to which actors belong provides cues to help them retrieve the record that they have stored in their memory. Regardless of how effectively an idea is encoded, if an environment does not regularly cue people to retrieve the idea, it is unlikely to persist and spread within the culture. Likewise, Hargadon and Douglas (2001) suggest that to gain social acceptance in the established field, institutional entrepreneurs should develop a "robust design" which embodies a new idea yet at the same time effectively exploits existing institutions. They argue that this familiarizing process reduces resistance to new logics while promoting social acceptance.

Interactions among social actors can be defined as a set of social actors' activities of conveying their knowledge to other social actors. Researchers suggest that the standardization or formalization of cues may help develop common understandings of the usefulness of novel knowledge, in turn facilitating institutionalization processes (Fligstein 2001; Carlile 2002; Adler 2005). In addition, the creation of new structures, orders or roles that provide incentives for coordination activities may also promote transmission of knowledge (Dougherty 1992). Brown and Duguid (1991) further argue that knowledge transmission is more likely to take place when social actors experience actual and informal practices that are generated and shared within the technological community.

Competition of institutional logics in the technology field mostly relates to discourse about the true meaning and value of technology. That is, primary debates in this field center on whether new technology can expand, given the restrictions and opportunities provided by existing technological and material substances; whether new technology can achieve techno-economic efficiency and generate desired outcomes, or whether socio-economic infrastructure supports new technology. If new technology does not satisfy the institutional logics shared by the technological community, it will not develop into taken-for-granted institutions, as the technological discussion will screen out this outcome.

While the technology field serves as a primary source of new knowledge and technology (Rosenberg 1982), technology entrepreneurs should continuously interact with actors in the sociocultural field where the actors eventually become the end users of the new technology (e.g., Garud, Jain, and Kumaraswamy 2002). Actors in those two fields may possess different institutional logics. A new technology created in the technology field triggers market-related discussions in the sociocultural field where technology users evaluate the value and usefulness of new technology based on their own institutional logics. An institutional logic in the sociocultural field includes a set of social actors' activities for reaching a consensus on the meanings of a new technology—and thus developing new norms, values, and beliefs revolving around the new technology.

Successful interactions between technology and sociocultural fields depend on the ability of technology entrepreneurs to communicate with technology users in order to develop shared understandings (Fligstein 2001). If technology entrepreneurs are creators of new logics associated with technology, institutional entrepreneurs are storytellers who govern narrative processes in the sociocultural field (Garud, Jain, and Kumaraswamy 2002; Lounsbury and Glynn 2001; Zilber 2007). The introduction of a new technology, by nature, produces numerous conflicts of interest among social actors who operate in the related technical and institutional environments (Biggart and Beamish 2003; Sewell 1992). A new technology often conveys a counter-story to existing technology. When it comes with ethical and normative issues, the harshness of language and emotional engagement can easily escalate (Zilber 2007). In order to become successful institutional entrepreneurs, technology entrepreneurs need to know how to cultivate social, political and institutional legitimacy at the broader institutional level. This can be done by managing the social and cultural resistance to adopting new technologies and practices (Aldrich and Fiol 1994; Fligstein 2001).

The traditional technological innovation model tends to neglect this social embeddedness of innovation processes through which a new technology gets widely accepted by other social actors and becomes a dominant design (Granovetter and McGuire 1998). Institutional entrepreneurs often act to shape the institutional logics of social actors or to modify a new technology to align it with the institutional logics of technology users (Hargadon and Douglas 2001). Furthermore, institutional entrepreneurs often create new social roles and structures in order to embed new technology into actors' everyday lives (Munir and Phillips 2005). For example, Munir and Phillips (2005) show how Kodak has managed to popularize photographic technology and has embedded this technology into institutionalized practices. As a result of its effort to communicate with technology users, Kodak can successfully transform photography from a specialized hobby of a limited social class to a central part of the daily lives of social actors, and can eventually create a new social role (i.e., creating a new role of housewives—creating family histories through photographs in the early 1900s).

More importantly, prevailing technology work has still revolved around how technology entrepreneurs can shape social structure and social order. How actors in the sociocultural field can act to shape technology development is relatively understudied. A few studies within the technology history literature have discussed the importance of the role of technology users in shaping technology evolution. For example, in the study of the early U.S. automobile industry, Kline and Pinch (1996) discuss how several different transportation technologies—such as gasoline- and steam-powered cars and electric cars in the U.S. automobile industry—evolved out of the technological, economic, social and cultural races of the early 1880s. Berger's (1979) study well illustrates how technology users determined the success of the internal combustion engine cars in the early 1880s. Despite the technological superiority of the internal combustion engine vehicles to horses, social actors, especially rural dwellers and state legislatures, initially opposed the dirty, noisy and dangerous internal combustion engine cars. Unexpected car accidents and the incompatibility of horses and motorized cars on the road strengthened the anti-car movements (Berger 1979; Kline and Pinch 1996). "Red devil" and "devil wagon" were terms that represented technology users' antagonism and soon symbolized the negativity toward the new technology of motorized cars (Kline and Pinch 1996).

However, in the early 1900s, possession of automobiles gradually expanded the lifestyles of rural dwellers' in more efficient ways. Socialization, leisure, church, health and education all became more accessible to the rural community due to motorized cars. This social process eventually allowed the internal combustion engine cars to completely replace old means of transportation (Berger 1979). In particular, compared to the potential of steam engine and electric cars, the long distance drive, power and speed of internal combustion engine cars has fascinated travelers and technical amateurs (Mom 2004; Sachs 1984). Ever since the First World War, internal combustion engine cars have dominated the automotive technology industry (Kirsch 2000).

Social movement scholars emphasize the roles of collective social and political processes in mobilizing people and resources to construct and reconstruct social goals, ideologies and cultural frames (for a review, see McAdam and Scott 2005). They argue that social movements serve as a new momentum that triggers the destruction of existing institutional logics and fosters the creation of a new institutional logic (Rao, Monin, and Durand 2003; Scott, Ruef, Mendel, and Caronna, 2000). Social movements stemming from a specialized social sphere can be easily generalized as an abstract-level ideology or logics which can easily diffuse into other social spheres (McAdam and Scott 2005). Certain issues of social movements thus often become a source of nationwide or worldwide debates.

In the technology context, social movements can serve as a source of the emergence of a new technology, by influencing social actors' choice of technologies. The emergence of new electric and hybrid vehicles illustrates well how generic social movements can influence the technology field. In the 1960s, environmental movements in the sociocultural field facilitated the resurgence of alternative fuel vehicles, such as electric cars (Anderson and Anderson 2010). They initially began by calling for protecting the environment from pollution and later influenced the development of environmentally-friendly technology (Pepper 1996). A wave of environmental movements in the 1960s facilitated the creation of grassroots environmental organizations and government organizations. As part of these efforts, in 1970 the U.S. Environmental Protection Agency was formed to facilitate the regulatory support for environmental protection. One of its goals was to support the research and development of alternative fuel vehicles. Other environmental organizations continued to exert social and political pressure on the industrial sector, by lobbying for raising environmental standards. Moreover, in the mid-1970s, the oil crisis increased social actors' awareness of natural resources, which fostered a skepticism about gasoline as a permanent energy source. These social movements strengthened an environmental logic, which has long generated new controversies and debates among environmental activists and industry associations since the 1960s (Sachs 1999). Scientists and engineers in the community of electric vehicle researchers adopted this environmental logic to promote the social and economic value of electric cars. The technologists' adoption of an environmental logic escalated conflict in logics in the technology field; and their adoption of an environmental logic facilitated the resurgence of electric vehicles beginning in the late 1960s. I therefore offer the following proposition:

Proposition 1. *Collective actions in the sociocultural field will influence the development of new technologies.*

1. 3. 4. Logic Formation and Types of Technology Development

Differences in institutional logics in technological and sociocultural fields generate controversies, thereby intensifying social conflict. As mentioned earlier, new technologies or institutional logics debated in the technology field provide sources or topics for market-level debates during which technology users express their opinions and feelings about new technology (e.g., Abrahamson and Fairchild 1999). Conversely, institutional logics of technology users can also facilitate or hinder the further development of new technology (Dowell, Swaminathan, and Wade 2002). New institutional logics, having met criteria in the technology field, may not develop into cognitively- and culturally-shared institutions unless they are accepted in the sociocultural field.

A critical question that needs to be addressed is how technologists respond to multiple and often conflicting institutional logics, and how variations in technologists' responses influence different types of technology development. The institutional entrepreneurship literature suggests that entrepreneurs with the ability to communicate with actors in the sociocultural field can more effectively transform new logics into socially- and culturally-accepted logics (e.g., Biggart and Beamish 2003; Fligstein 1997; 2001). Such entrepreneurial activities provide legitimacy for new technology; and the attainment of legitimacy increases the survival rate of new technology (Aldrich and Fiol 1994).

Different responses of institutional entrepreneurs may drive different types of technology development. Considering the strength of technologists' and social actors' support for a new institutional logic, I propose four distinctive institutionalization mechanisms and their influences on technology development.

*** Insert Figure 3 about here ***

The first institutionalization mechanism of institutional logics is *replacing*. This mechanism describes how a newly-created or newly-adopted logic completely replaces an existing logic. Thornton's (2002) study on the higher education publishing industry demonstrates that publishing firms faced with environmental changes have gradually transformed existing editorial logics, focusing on editors' social relations to market logics, and placing more emphasis on business models over the course of the past thirty years. This is because new publishing markets have forced publishing companies to focus more on economic outcomes. The results show that broader economic conditions have created a new market logic and that actors have strategically replaced the old editorial logic with the new market logic to conform to changes in the sociocultural field.

Similarly, the *replacing* mechanism can take place in the technology context. The example of the emergence and decline of the internal combustion engine and electric cars provides evidence about how a new logic can completely replace an old logic. Prior to the invention of the internal combustion engine, an agricultural logic had dominated the pre-industrial society and had been closely attached to actors' everyday lives. However, the advent of the internal combustion engine ushered in a new era of the industrial society. Actors in the social and cultural field believed that economic growth provided economic wealth and job opportunities (Hays 1995). Primary concerns of technologists in the technology field were also related to techno-economic efficiency, infrastructure and markets, all of which made up an industrial logic.

This industrial logic further strengthened the dominance of the internal combustion engine (Hays 1995; Mom 2004). Actors viewed that internal combustion engine vehicles functionally outperformed horse-drawn vehicles and met contemporary social needs. Furthermore, infrastructure (i.e., gas stations, oil refinery facilities, etc.) had been built and were ready to support the use of internal combustion engine cars (Mom and Kirsch 2001). The creation of new collective beliefs—industrial logic—resulted in deinstitutionalization of old beliefs—agricultural logic. Shifting the agricultural logic to the industrial logic in both technology and sociocultural fields fostered the transition from the horse-and-buggy age to the horseless age. I therefore propose the following:

Proposition 2a. *When a new logic is strongly supported by both technological and sociocultural groups, technologists will replace the existing logic with a new logic.*

Proposition 2b. *The replacement of an existing logic by a new logic will lead to disruptive technological development.*

Another institutionalization mechanism is *patching*. In some case, a new institutional logic may not be able to completely replace an old one. When an existing logic is closely and extensively connected to the cultural and social lives of actors, it is not easy for actors to completely replace an old logic with a new logic. This is because the *replacing* mechanism incurs fairly large social and economic costs, takes a fairly long time to engage in sense-making processes and generates extensive conflicts of interests among different social groups with different institutional logics (Garud and Karnøe 2001). Thus, if actors in the sociocultural field do not strongly support a new logic while technologists strongly do support the new logic, then the mere addition or modification of a prevailing logic can occur in the technology field. In particular, if both old and new logics are equally significant, technologists may act to combine the two logics to minimize social conflicts (c.f. Oliver 1991). Furthermore, if the new and old logics are complementary, a combination of the two logics may decrease social conflict but increase the level of social acceptance. This *patching* mechanism would subsequently lead to hybridization of new and old technologies.

For example, in their study of critics' reviews of Atlanta Symphony Orchestra performances, Glynn and Lounsbury (2005) demonstrate that because an authenticity logic has long served as a cultural frame for assessing the performance of the Atlanta Symphony Orchestra, the judgments of critics have still used the authenticity logic although there has been an external shock favoring a commercially-oriented market logic. As a result, instead of discarding the authenticity logic, critics have often incorporated some elements of the market logic into the authenticity logic.

Likewise, in the technology context, Hargadon and Douglas (2001) show how purposefully Edison customizes electric lighting (new technology) without dramatically changing preexisting schemas and scripts for gas lighting (old technology). They demonstrate that by imitating the features of gas lighting, Edison has shaped the existing mindsets or beliefs of customers, regulators and even investors, and has helped them to easily understand the meanings, usefulness and purposes of new electric lighting systems. When existing technology has been long embedded within the sociocultural field and has been shaping social structure and order, technologists may attempt to explore the way in which they incorporate some elements of a new logic into an existing logic (Fligstein 2001). Edison's *patching* effort results in hybridization of old and new technologies.

In addition, Kaplan and Murray (2010) also show how technologists modify a prevailing economic logic which has long influenced the biotechnology industry over the course of thirty years. In the 1970s, biotechnology firms focused on building a standard business model by which firms could successfully commercialize biotechnologies. The initial focus was on setting a right business model. Unlike biotech firms, courts, government agencies, scientists and markets placed different values on the commercialization of biotechnologies. A wide range of actors associated with the biotechnology industry mobilized testing evidence, providing new interpretations of evidence. To accommodate the needs from different institutional fields, firms had begun to add new issues such as safety, intellectual property and economic development to the initial economic logic. Throughout this process, actors within the community of biotechnologies collectively reconstructed the value of evidence and played an important role in modifying an initial economic logic. Furthermore, this *patching* mechanism of institutional logics led to a series of multidisciplinary research studies which take into account all concerns of multiple actors associated with the biotechnology community. I therefore offer the following propositions:

Proposition 3a. *When a new logic is strongly supported by technological groups but is weakly supported by social groups, technologists will patch a new logic over an existing logic.*

Proposition 3b. *The patching mechanism will lead to hybridization of new and existing technologies.*

The third mechanism is *sequencing*. When institutional entrepreneurs believe that a new logic may not be able to win the battle of institutional logics, they can develop a temporary logic to popularize the new logic (e.g., Munir and Phillips 2005). In the early history of the U.S. automotive industry, the upper social class did not accept gasoline-based internal combustion engine cars as a means of transportation, because motorized cars were perceived as a dirty, noisy, dangerous and unreliable means of transportation, compared to horses, the traditional means (Berger 1979). In contrast, electric cars were elegant, quiet and technologically advanced, compared to the internal combustion engine cars (Kirsch 1996). In the early motor age, electric vehicles played an important role in popularizing motorized cars and destroying emotional and cultural resistance to using motorized cars. Gradually, the gasoline-based internal combustion vehicles soon surpassed social actors' cultural expectations (Mom and Kirsch 2001). Around the early 1900s auto manufacturers could introduce faster, more efficient, more powerful and more reliable gasoline-based internal combustion cars, which led to dominance of gasoline-based internal combustion engine vehicles. That is, electric vehicles played the role of "Trojan Horse" over the course of the transition from the horse age to the horseless age (Mom 2004).

The emergence of hybrid vehicles is another example of technological development that results from the *sequencing* mechanism of institutional logics. After intense technology competition among gasoline-powered, steam-powered and electricity-powered cars during the period of 1880-1920, internal combustion engine vehicles dominated the motor industries (Kirsch 2000; Mom 2004). However, a small group of scientists and engineers continued to develop electric vehicles to prepare for "the second battle" (Kirsch 2000). In particular, the aesthetic features of electric vehicles such as simplicity, technical elegance, cleanliness and minimal noise drew attention to scientists and engineers (Kirsch 2000). Later, environmental groups joined in the promotion of electric vehicles as an alternative to internal combustion engine vehicles. Air pollution, global warming, the growing scarcity of natural resources, and corporate social responsibility demanded alternative vehicles, which stimulated legislative efforts and social movements. Finally in 1967 the Electric Auto Association (EAA), a local electric car organization was formed by Walter Laski in San Jose, California to promote technological advancement and the widespread adoption of electric vehicles. Relatedly, in 1969 a group of scientists and engineers who had passionate interests and optimistic beliefs about the future of electric cars formed the international *Electric Vehicle Symposium* which has now become a major international research conference among the community of electric automotive technology researchers.

Despite the wave of environmental movements in the 1960s, this was not an easy battle for a small number of social and technical groups, because gasoline-based internal combustion engine cars had long been dominating the worldwide automobile markets. When assessing the future of electric vehicles, even scientists and engineers largely relied on techno-economic criteria such as economic benefits and costs of electric cars, techno-economic efficiency and viability of infrastructure, all of which represent an institutional logic used to bolster gasoline-based internal combustion cars—in other words, an industrial logic.

Moreover, while environmental activists strongly supported alternative fuel vehicles, including electric vehicles, some social actors in the sociocultural field were skeptical about the commercial value of electric vehicles. They believed that in terms of technical instrumentality, the internal combustion engine cars outperform, that they are economically efficiency, and have technological superiority (i.e., power, mileage and speed) and benefit from well-established infrastructure (i.e., gas stations). This situation implies that once a certain institutional logic is taken-for- granted within the institutional field, the legitimate logic strongly influences actors' behaviors and cognitive/cultural frames (e.g., Glynn and Lounsbury 2005; Lounsbury 2007).

In the 1960s, when scientists and technical policymakers considered hybrid vehicles[1] as a viable alternative to internal combustion engine cars, they believed that pure electric vehicles would replace a substantial number of internal combustion engine vehicles by the early 2000s (Hoffman 1967; Wouk 1971). The emergence of

[1] The original concept of hybrid vehicle was introduced in 1905 when Henri Pieper filed for a patent.

hybrid vehicles exemplifies an evolutionary development of automotive technology. I therefore offer the following propositions:

Proposition 4a. *When a new logic is strongly supported by social groups but is weakly supported by technological groups, technologists will first use the existing logic but will gradually adopt a new logic.*

Proposition 4b. *The sequencing mechanism will lead to evolutionary technological development.*

A final mechanism of incorporating institutional logics is *reinforcing*. It is possible that actors in both technology and sociocultural fields resist adopting a new logic. Rather than passively adopting a new logic or modifying their existing logic, actors often purposefully engage in political, social and economic negotiations in order to shape other actors' frames and reinforce their own logic. Once a certain institutional logic is taken for granted, it tends to be "locked-in" within the institutional environment, which hinders subsequent institutional change (North 1990).

In addition to actors, other institutions such as regulations, technical standards and media help to stabilize the contestation among multiple institutional logics (c.f., Könnölä, Unruh, and Carrillo-Hermosilla 2006; Unruh 2002). In the technology context, Könnölä, Unruh and Carrillo-Hermosilla (2006, p. 240) view this phenomenon as *techno-institutional lock-in*, "a persistent state that creates systemic market and policy barriers to technological alternatives."

Regulations and technical standards that are favorable to existing logics and technologies can hinder the creation of a new logic or a new technology. A body of literature on industry standards demonstrates that the achievement of industry standards helps firms to maintain increasing returns resulting from economies of scale or precluding further entry (e.g., Arthur 1989; 1994; David 1985). In a case study of the success of Ethernet, Von Burg (2001) describes the process through which Robert Metcalf, former CEO of Ethernet, was able to manage partnerships with other firms and form the Ethernet community which helped create the LAN standard.

In addition, the media also play a critical role in spreading existing norms, beliefs, values, practices and technology over the broader range of audience (Lampel 2001). Media often create a dramatic story about a certain technology which enhances its market position. Once institutional logics become taken for granted and technology becomes a dominant design, such "techno-institutional lock-in" often hinders the further development of new technology. I therefore offer the following proposition:

Proposition 5a. *When a new logic is weakly supported by both social and technology groups, technologists will persistently use the existing logic.*

Proposition 5b. *A reinforcing mechanism will hinder new technological development.*

1. 4. Discussion

In this chapter I provide a theoretical model that accounts for how actors can collectively shape future technology development via the formation of institutional logics. I particularly seek to theorize about linkages between actors' formation of institutional logics and types of technological evolution. This study has several theoretical and practical implications. First, this study helps to better understand the process of institutional change. A fundamental question that has been long debated is this: How can embedded actors whose activities tend to be constrained by wider institutional forces implement institutional change? One line of studies on institutional change has argued and empirically demonstrated that external shocks and internal performance crises can serve as sources of institutional change (e.g., Barley and Tolbert 1997; Oliver 1992; Tolbert and Zucker 1983). Another line of studies focusing more on micro-dynamics has contended how embedded actors manage institutional contradictions and misaligned interests of actors during the institutional change (e.g., Seo and Creed 2002). Less is however known regarding how *differently* embedded actors respond to competing institutional logics, manage conflict of institutional logics and in turn drive institutional change.

In this chapter I therefore have sought to address this theoretical gap, suggesting that actors collectively shape the formation of institutional logics. In addition to the endogeneity of institutional logics, the model proposed in this chapter also implies that institutional logics can be enablers and disablers of institutional change. This situation suggests that different formation of institutional logics can drive different types of institutional change. A new institutional logic can drive institutional change when social groups support the new logic, whereas an existing logic can hinder institutional change when social groups reinforce the existing logic. In the context of technological evolution, technologists encounter multiple institutional logics associated with technologies. A certain institutional logic would help understand the usefulness of technology but at the same time would preclude the adoption of other technologies associated with different institutional logics. Successful management of competing logics depends on how effectively actors convince other actors who possess different institutional logics.

Second, this study contributes to a longstanding debate regarding whether technology determines social structure and order or whether social forces shape the development of new technology. While technology determinism supports the former, some scholars argue the latter, suggesting that human agents can actively disrupt meaning systems, values, and norms within the current institutional boundaries (e.g., Barley and Tolbert 1997; Purdy and Gray 2009). While current agency-based studies on technology have contributed to the development of a structuration model of technology, most studies still tend to treat technology as a *given* and then explore social processes of how social actors generate different meanings of new technology, and subsequently develop differential social structures and roles as a result (e.g., Barley 1987; Orlikowski 1992).

Less is known regarding *collective mechanisms* influencing development of new technology. The social mechanisms of incorporating different institutional logics can help us to understand the reciprocity between actors and institutions in the context of technological evolution. In particular, I show how institutional logics mediate between actors and technologies. Institutional logics are manifestations of social actors' interpretations of technology. They are social and cultural outcomes of interpreting new technology, but at the same time constrain actors' interpretations of other technologies. Logic formation includes the following processes: actors collectively develop institutional logics and share their meanings within a community; established institutional logics guide social actors' cognitive thought-processing; and different interpretations of institutional logics create social conflicts and lead to the creation of another formation of institutional logics.

Third, this study contributes to the current technology literature by exploring endogenous social and cultural processes of technological evolution that are relatively overlooked in the current technology studies. Early research on the history of economic development has long argued that universities, scientific laboratories, and industries' research and development are sources of new knowledge; and this early research has found that it is necessary to explore the endogenous process of technological development (e.g., Rosenberg 1982; 2000). However, we know relatively little about the origin, development, and consequence of scientific knowledge (Kuhn 1970). Particularly, less is known about social processes through which social actors collectively interpret new technology or knowledge, and how institutions or collective mindsets of actors restrict actors' interpretations of new technology. In this chapter I propose four distinctive social mechanisms for framing institutional logics, and I link them to the types of technology development. This approach helps to better understand the social aspects of technology development and, to some extent, addresses why a certain technology, despite its technological superiority, does not become a dominant design and soon disappears in the society.

Fourth, identification of four differential mechanisms of the evolution of institutional logics provides strategic implications for entrepreneurs. This helps entrepreneurs develop appropriate strategies when they introduce new technology. To be successful institutional entrepreneurs, technology inventors should develop appropriate strategies for communicating with relevant social actors (Fligstein 2001; Hallen and Eisenhardt 2011; Hargadon and Douglas 2001). When introducing new technology or entering new markets, entrepreneurs may have to choose strategies of delivering relevant logics associated with new technology, products and services, or often shaping existing logics. Conflict in institutional logics can take place across different institutional fields. Thus alignment of institutional logics across all groups of relevant social actors, such as scientists, engineers, industry professionals, policymakers and technology users, is crucial for successfully launching a new technology. Four mechanisms discussed in this chapter can serve as basic guidelines for entrepreneurs' entry strategies.

Finally, the linkages between institutional logics and types of technology development highlight the importance of entrepreneurial activities associated with framing institutional logics. The model suggests that the formation of institutional logics is an underlying mechanism shaping technology development. Thus, an important question for entrepreneurs or managers may be how they should design their technology in order to acquire support from technologists and technology users.

In this chapter I suggest that technology development is an outcome of collective social processes among actors. Based on this assumption, I have sought to theorize about the relationships among actors, institutional logics and technology development. In this model I argue that actors play an integral role in technology development via the logic construction mechanisms.

Chapter 2: Social Movements, Institutional Logics and the Emergence of Electric and Hybrid Drive in the Electric Automotive Community from 1969-2009

Building upon the theoretical model discussed in Chapter 1, I empirically examine the casual linkages among socio-economic conditions, institutional logics and technology development in the context of the evolution of electric and hybrid drives. Combining the perspectives of institutional logics and social movements, I argue that an institutional logic is a product of the collective social processes of actors and that established logics play a central role in shaping the differential development of new technology. To test my arguments, I explore variations in the incorporation of institutional logics by actors, depending on broader social and economic conditions and the effects of the actors' incorporation of institutional logics on the evolution of electric and hybrid drive in the electric automotive community from 1969-2009.

Empirical findings suggest that environmental protests and economic recessions systematically influence an actor's incorporation of logics—environmental logic versus industrial logic; and that social cohesion among actors in each institutional logic field tends to substantially influence the emergence and decline of electric and hybrid drive. This study contributes to both technology and institutional literature by exploring how social and economic conditions relate to the ebb and flow of institutional logics and how institutional logics can shape technology development. Moreover, this study addresses a gap in the literature between institutional and social movement arguments, which together help us to better understand the complexity of institutional change and technology development.

2. 1. Introduction

Since Alford and Friedland (1985) coined the term institutional logics, scholars have been increasingly interested in the role of institutional logics. The linkage between institutional logics and organizational forms or practices has been widely studied (Marquis and Lounsbury 2007; Lounsbury 2007; Thornton 2002). Departing from the unitary isomorphism arguments, much research on institutional logics has centered on multiplicity and conflict in institutional logics (Jones and Livne-Tarandach 2008; Lounsbury 2007). It is now well-documented that multiple institutional logics result in differential development of beliefs, practices and organizational forms (Greenwood, Díaz, Li, and Lorente 2010; Lounsbury 2007; Rao, Monin, and Durand 2003).

While research on institutional logics has shown how actors respond to multiple and conflicting logics, we know less about the origin of institutional logics and the social and institutional forces responsible for changing or replacing existing institutional logics. Moreover, empirical research on institutional logics assumes that institutional logics are relatively stable and exogenously given. Consequently, operationalization of institutional logics tends to consist of relatively arbitrary identification and periodization, thereby limiting opportunities to study the ebb and flow of institutional logics.

More importantly, little research has examined the effect of the strength of institutional logics on actors' cognitive and behavioral patterns. If multiple institutional logics exist, how do actors respond to multiple logics? Do variations in strong beliefs of actors make any difference in terms of their responses to multiple logics? These questions, although fundamental, still remain unanswered.

More recent research on social movements provides theoretical insights into how institutional logics can change, and how competing logics can destabilize the institutional field (Hoffman 1999; Rao, Monin, and Durand 2003). Social movement scholars suggest that actors collectively and purposefully create a unique group identity and social roles, secure necessary resources, reframe existing logics, and ultimately challenge current social structure and institutions (e.g., Benford and Snow 2000; McCarthy and Zald 1977; Rao, Monin, and Durand 2003; Tilly 1978). Building upon this theoretical insight, much empirical work on social movements has centered on changes in public policies and programs, practices, and organizational form (Davis and Thompson 1994; Greenwood, Hinings, and Suddaby 2002; Lounsbury, Ventresca, and Hirsch 2003; Schneiberg, King, and Smith 2008). However, little is known regarding the linkage between social movements and technology development (see Sine and Lee 2009 for an exception).

In this study I therefore investigate the linkages among social movements, institutional logics, and technology development. That is, I seek to address how social movements outside the boundary of a given technological community shape technologists' incorporation of competing institutional logics within the technological community, and how the degree of technologists' beliefs about their institutional logics can influence technology construction. To do this, I examine the effects of environmental movements and economic conditions on technologists' incorporation of institutional logics, and the effect of their incorporation of institutional logics on technology construction in the international community of electric and hybrid vehicle researchers from 1969-2009. Empirical findings show that social movements and economic conditions are closely related to the ebb and flow of environmental and industrial logics, and that social cohesion within the two logics shapes differential development of electric and hybrid drive.

In this study I focus on the endogenous social and institutional processes associated with new technology development. In particular, I bridge the gap between social movements and institutional arguments by theorizing and empirically testing how social movements can play an integral role in logic incorporation. Moreover, I assume that institutional logics are neither stable nor enduring. With this assumption, I empirically demonstrate how institutional logics can gain or lose their legitimacy and power, depending on prevailing social and economic conditions. Furthermore, to my knowledge, this is the first study which measures and tests the effect of the strength of institutional logics on technology development. Finally, I extend our understanding of technology development into the social and institutional spheres by examining how contestation in institutional logics determines differential trajectories of technology development.

2. 2. Theory and Hypotheses

Institutional logics have become increasingly important for recent institutional studies. Institutional logics are "the socially constructed, historical patterns of material practices, assumptions, values, beliefs, and rules by which individuals produce and reproduce their material subsistence, organize time and space, and provide meaning to their social reality" (Thornton and Ocasio 1999, p. 804). Because institutional logics are considered to be supra-organizational patterns that constitute shared principles (Friedland and Alford 1991), they provide cognitive and behavioral guidelines for actors embedded within the institution. Following this insight, scholars have shown that institutional logics shape actors' strategic actions. Examples include: attention strategies (Thornton and Ocasio 1999), contractual practices with clients (Lounsbury 2007), investment decisions (Hallen 2008), and downsizing behaviors (Greenwood, Díaz, Li, and Lorente 2010). Although these studies have revealed the pluralistic attributes of institutional logics and have sought to go beyond unitary isomorphism arguments (see Kraatz and Block 2008 for a review), their empirical findings still revolve around the behavioral outcomes of multiple institutional logics. What remains unanswered is how a new logic is created and how current logics, more precisely, actors embedded within existing logics, respond to a new logic.

Social movement arguments tend to provide theoretical insights into the dynamics of changes in institutional logics (see McAdam and Scott 2005 for a review). A social movement is "a set of opinions and beliefs in a population which represents preferences for changing some elements of the social structure and/or reward distribution of a society" (McCarthy and Zald 1977, pp. 1217-1218). Social movement theorists tend to suggest that institutional logics are neither stable nor enduring (Benford and Snow 2000). They argue that actors' discontent, conscience, or morality is a source of changing current beliefs, norms and practices (McCarthy and Zald 1977; Tilly 1978). Collective actions facilitate demobilization, and remobilization, of current resources and cognitive reframing processes (Benford and

Snow 2000; Snow, Rochford, Worden, and Benford 1986; Weber, Heinze, and DeSoucey 2008). For example, Rao, Monin, and Durand (2003) showed that French *nouvelle cuisine* movement activists created a new professional logic associated with cuisine, and that the new logic redefines the roles of chefs and induces new social identity for this group.

This social movement theory suggests that actors' collective actions can be one of the major forces for creating a new institutional logic or remobilizing the existing logics. The question that then arises is how contestation in multiple institutional logics is related to technology development. I discuss this in greater detail in the following sections.

2. 2. 1. Interplay between Social and Technological Fields

Social movement scholars assert that social movements which originally grew out of a certain social group's special interests can be generalized as supra-group ideology (McAdam and Scott 2005). Benford and Snow (2000) argue that actors' collective frames are not merely limited to a certain social movement organization or its special interests. Some frames incorporate generic social problems, and thus they function as a master frame which influences social actors in different institutional arenas (e.g., Clemens 1993; Neustadtl and Clawson 1988; Schneiberg and Soule 2005). For example, in their study of the effect of consumer boycotts on a firm's stock price, King and Soule (2007) showed that social movements associated with consumers' discontent with products can affect investors' valuation of stock price in the money market through media attention.

This "transgressive" nature of social movements hints that collective actions outside the boundaries of the technological field can also influence technology development. In considering the creation, development and diffusion of technology, technological and sociocultural fields are indeed not separate (Garud and Kumaraswamy 1995; Thornton and Ocasio 2008). For example, in their study of the emergence of Kodak camera technology, Munir and Phillips (2005) demonstrate how closely technologies, social roles and practices are linked together. They found that Kodak's strategy of embedding its camera technology in actors' everyday lives played a central role in its technological success.

The history of automotive technology also vividly illustrates how actors in the social and cultural field collectively impact the emergence of hybrid drive (which is designed to use both an internal combustion engine and an electric motor to operate the vehicle). Actors have long believed that mass production systems, development of infrastructure, technological innovation and efficient use of natural resources will allow for economic growth, which ultimately provides the community with jobs and entrepreneurial opportunities, and in turn brings economic wealth (e.g., Chenery, Robinson, and Syrquin 1986; Murphy, Shleifer, and Vishny 1989). These beliefs constitute an industrial logic in the U.S. that dates back to the early 1900s (Hays 1995). As a countermove against this industrial logic, environmental activists and conservationists have advocated the preservation of the environment, claiming that industrialism has destroyed national environments and threatened human lives (e.g., Pepper 1996). Starting from local protests against polluters, environmental movements soon grew into a national movement in the 1960s and facilitated the new formation of grassroots environmental movement organizations as well as the expansion of long-standing social movement organizations such as the *Sierra Club*, the *Wilderness Society*, and the *National Audubon Society* (Gottlieb 2005; Rothman 1998). During this period, environmental beliefs were bundled with other social issues such as race, gender, war, culture and political faith and became part of American liberalism (Isserman and Kazin 2004). A group of actors believed that protection of the environment from economic development provides better opportunities for both humans and non-humans to prosper together. These beliefs constitute an environmental logic. Table 1 summarizes these two logics.

*** Insert Table 1 about here ***

A series of environmental actions in the 1960s resulted in a string of legal and political successes. The first Earth Day was held on April 22, 1970, inspiring environmental awareness and spurring nation-wide environmental protests. On December 2, 1970, environmental movements helped establish the U.S. Environmental Protection Agency (EPA), which monitors environmental pollution, sets environmental standards and influences policy on environmental issues. In 1970, the EPA influenced the extensive amendment of the Clean Air Act that was originally passed by the U.S. Congress in 1963. The amended Clean Air Act covered requirements for control of motor vehicle emissions, including regional requirements. The EPA continued to play an active role in further amendments of the Clean Air Act in 1977 and 1990.

In 1969, at the peak of unrest in American society, a group of electric engineers, scientists and policymakers convened the first *Electric Vehicle Symposium*

(EVS) where they exchanged technical information associated with electric vehicles and developed global networks. Environmental movements motivated academic, government and industry professionals to reconsider electric vehicles as an alternative to the internal combustion engine vehicles. Technical professionals incorporating an environmental logic discussed pollution, air environments, human value and social pathology in this symposium.

The above illustration demonstrates that societal-level norms, values and ideology are closely related to technology community. Social movement theory suggests that collective actions intended to change the undesirable status quo at a certain institutional field often impact norms and values in other institutional fields (see McAdam and Scott 2005 for a review). Likewise, environmental movements have influenced the development of new automotive technology. Actors in the sociocultural field are indeed potential end-users of technology, and thus their values, beliefs and norms often shape institutional logics in the technological field (e.g., Sine, Haveman, and Tolbert 2005). Moreover, although actors within the technological field can create a new logic through technological innovation, other actors in the sociocultural field can occasionally inject a new logic to the technological field through the formation of social movements (Sine and Lee 2009). Therefore I propose the following hypotheses:

Hypothesis 1a: *Environmental protests in the sociocultural field will increase the likelihood of an actor's incorporation of an environmental logic in the technological field.*

Hypothesis 1b: *Environmental protests in the sociocultural field will decrease the likelihood of an actor's incorporation of an industrial logic in the technological field.*

Social movements associated with regulatory efforts and protests against pollution required business sectors to make significant investments into the reduction of pollution and limited their exploitation of resources. Significant investments to meet environmental standards crowded out firms that were not cost-efficient. A series of economic recessions in the mid-1970s, the early 1980s, the early 1990s, and the early and late 2000s brought about high unemployment rates, business failures and a slump in the manufacturing and service sectors. Economic recessions weakened environmental movements and allowed for more input from economic sectors. Labor unions joined the industry associations to protest against draconian environmental standards, which put cost pressure on business sectors, thereby resulting in massive layoffs. Those social groups pressured governments to lower environmental standards. Furthermore, labor unions and workers—particularly in the steel, oil, mining and automobile industries—often attributed huge layoffs to environmentalists' idealism. Figure 1 illustrates the enduring tension between environmental and industrial logic. It shows that the number of environmental protests dramatically decreases when the unemployment rate increases.

*** Insert Figure 4 about here***

This countermove also strongly influenced a series of discussions within the technological community. While one of the main goals of the international EVS was to reduce air and noise pollution resulting from internal combustion engines, an industrial logic has widely influenced the development of electric vehicles. Some actors within the technological field paid attention to economic efficiency (primarily cost reduction), competitive price, marketing, standardization, commercialization and infrastructure, all of which represented an industrial logic. An industrial logic became a more convincing voice among arguments, particularly during the economic recessions. I therefore offer the following hypotheses:

Hypothesis 2a: *Economic recessions in the sociocultural field will decrease the likelihood of an actor's incorporation of an environmental logic in the technological field.*

Hypothesis 2b: *Economic recessions in the sociocultural field will increase the likelihood of an actor's incorporation of an industrial logic in the technological field.*

2. 2. 2. Institutional Logics and Technology Development

As I mentioned earlier, the existing literature on institutional logics has shown that institutional logics provide cognitive and behavioral guidelines which shape the patterns of social actors' activity (Friedland and Alford 1991; Thornton and Ocasio 1999). More recent institutional research investigates the role of institutional activities of actors in creating institutional change (c.f., Zietsma and Lawrence 2010). Scholars apply the concept of *institutional pluralism* which considers the situation where actors tend to face multiple, and often conflicting institutional logics within their institutional field (e.g., Kraatz and Block 2008; Marquis and Lounsbury 2007). Empirical research has demonstrated several factors: that multiple and competing institutional logics can coexist in different regions (Lounsbury 2007), that a new logic can replace an existing logic (Rao, Monin, and Durand 2003), that an existing logic can incorporate a new logic (Glynn and Lounsbury 2005), and/or that multiple logics can differentially influence actors' behaviors (Greenwood, Díaz, Li, and Lorente 2010).

The underlying rationale of the institutional logic argument runs as follows: introduction of a new logic creates discourses and tensions within the existing institutional field (Phillips, Lawrence, and Hardy 2004). Actors supporting a new logic form a social group, construct a new group identity, and develop shared beliefs to establish the legitimacy of the new logic in the field (Davis and Thompson 1994; Rao, Monin, and Durand 2003; Tilly 1978). In contrast, actors rejecting the new logic enforce their own logic and isolate themselves from the new logic in order to protect their own beliefs (Marquis and Lounsbury 2007). This institutionalization process deepens conflict in logics, which often leads to additional logic formation.

Similarly, in the technological field, multiple and competing institutional logics can influence technological evolution. Bijker (1987) stresses the role of technological frames defined as a set of community-level theories, tacit knowledge and daily practices that help solve problems in technology development. Scholars suggest that a group of scientists and engineers who share similar values, beliefs and norms tend to use their own technological frames to understand the meaning and socio-economic value of new technology (e.g., Orlikowski and Gash 1994; Pinch and Bijker 1987).

In a similar vein, other scholars building upon community of practice approaches suggest that practices shared by group members foster the sharing of knowledge and thus promote group learning and innovation (e.g., Brown and Duguid

1991; Lave and Wenger 1991; Orlikowski 1992). When social groups with different technological frames are competing, each group tends to promote its own frame or often redefines it.

The notion of technological frame is not limited to the technologists' frame. Rather, Bijker (1987) suggests that it incorporates frames of consumers and manufacturers, as well as technology inventors, revolving around technology. The technological frame thus reflects institutional logics in the technological field. Akrich (1992) further argues that technology is realized as a way of inscribing inventors' beliefs about the relationship between technology and its users, suggesting that technology and community of practices co-evolve.

Institutional scholars argue that the extent to which an institutional logic is taken for granted in a certain institutional field determines the differential evolution of social practices (Greenwood, Díaz, Li, and Lorente 2010; Lounsbury 2007). Following this theoretical insight, the prevalence of institutional logics or institutions has been considered a proxy of the degree to which a logic is "taken-for-granted." While the breadth of shared beliefs of actors somehow captures the degree of taken-for-grantedness, it does not necessarily reflect the strength of actors' collective beliefs. Actors' mimetic adoption resulting from their legitimacy-seeking behaviors can take place during the diffusion of new practices or technologies. However, when it comes to institutional change where actors deconstruct an old institution and create a new one, the absence of strong beliefs may not lead to institutional change. There has not been sufficient institutional research to examine the role of the strength of shared beliefs, particularly *connectivity* among actors who share the similar institutional logic.

The importance of the strength of collective beliefs has been discussed in different literatures. Bijker (1987) argues that technologists' strong inclusiveness in their technological frame tends to hinder their adoption of other technology distant from their own frames, thereby stalling breakthrough technological innovation. In addition, social movement theory also highlights that actors' strong commitment to shared beliefs promotes group members' exchange of information and resources within the group—and thus increases the effectiveness of collective actions (e.g., Tilly, 1978).

As I discussed earlier, an environmental logic has long competed with an industrial logic in the electric vehicle arena (e.g., Sachs 1999). In considering the history of automotive technology during the period of 1969-2009, it is evident that the emergence of hybrid drive is an outcome of *logic contestation*. Although electric vehicles have been regarded as a cleaner, technically more efficient and less noisy technology, an industrial logic supported by business sectors, labor unions and a group of engineers has been blunting the optimism about electric vehicles. Whether electric vehicles can achieve technical and economic efficiency or whether the existing infrastructure is compatible with electric vehicles has been long discussed in the technological and sociocultural fields (Kirsch 2000; Sachs 1999).

While an environmental logic has provided social and cultural support for the further development of pure electric drive, an industrial logic hinders the emergence of pure electric drive that requires significant investments in infrastructure and technological improvement. Competition between the two logics resulted in the creation of a new technology—hybrid drive which incorporates both environmental and industrial logics. In particular, when both logics strongly influence the technological field, rather than one dominating the other, hybrid drive will be more likely to emerge. This is because stronger contestation between the two logics triggers public and hostile debates which force actors to seek some form of hybridization (Glynn and Lounsbury 2005; Schneiberg and Bartley 2001). I therefore offer the following hypotheses:

Hypothesis 3: *Stronger cohesion networks among actors in an environmental logic will increase the likelihood of an actor's acceptance of pure electric drive in the technological field.*

Hypothesis 4: *Stronger cohesion networks among actors in an industrial logic will decrease the likelihood of an actor's acceptance of pure electric drive in the technological field.*

Hypothesis 5: *Stronger cohesion networks among actors in both industrial and environmental logics will jointly increase the likelihood of an actor's acceptance of hybrid drive in the technological field.*

2. 3. Method

2. 3. 1. Data

Professional meetings have been identified as a critical locus of open discussion of new technology and innovation (e.g., Waguespack and Fleming 2009). To explore an actor's incorporation of new institutional logics and technologies, I analyze the proceedings of the international *Electric Vehicle Symposium* (EVS) from 1969-2009. The EVS began in 1969 in Phoenix, Arizona as a forum where scientists, engineers and policymakers could exchange technical information about electric vehicle technologies. Forty years later, this symposium has expanded to play a critical role in introducing the state-of-the-art technologies associated with electric transportation into global markets. A total of 24 volumes of EVS proceedings have been published by symposium organizers as of 2009 (See Table 2 for an overview). The EVS proceedings are not uniform over the study period, but they usually include research papers, authors' institutional affiliations and brief biographies, countries of origin, authors' contact information, organizing committees, sponsors, exhibitors, and technical specifications of on-site technology demonstrations called "ride and drives."

*** Insert Table 2 about here ***

Information about authors' country of origin, institutional affiliations, paper titles, keywords, abstract and main texts was extracted from the original proceedings. This initial sample includes 6,926 authors from 57 nations authoring 3,282 papers. Among these authors, 44% are scientists, engineers and researchers who work for firms; 34% of authors are from universities; and 15% are affiliated with government-sponsored research institutions or independent private research institutions. Government and municipal officials comprise 5% of authors. Others include politicians and non-government organizations.

Data were constructed at the author-level to allow for the examination of an author's incorporation of institutional logics and technologies. In total, my initial sample has 11,680 author-year observations. Because it takes time to publish research papers at the conferences, I lagged some of the variables in my specifications (I describe this in detail below). Creating lagging variables excludes the first and second proceedings from the initial sample EVS 1 and 2. As a result, the final sample includes 6,711 authors, 3,155 proceedings and 11,421 author-year observations.

To measure the intensity of social movement activity, I obtained environmental movement events from the *New York Times*. The social movement literature has demonstrated that national newspapers are valid sources for capturing social movement activity (e.g., Earl, Martin, McCarthy, and Soule 2004; Kennedy 2008; King and Soule 2007). Moreover, King and Soule (2007) specifically show that news articles about social movement events collected from the *New York Times* are more comprehensive than articles from other national newspapers such as the *Washington Post* and the *Wall Street Journal*. I thus use the *New York Times* to obtain information about environmental protests from 1969-2009.

Finally, to measure prevailing economic and environmental factors, I collected annual U.S. unemployment rates, U.S. oil and gas prices, average domestic passenger car prices, and carbon dioxide emissions from the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor Statistics, the U.S. Energy Information Administration and the U.S. Department of Energy.

Annual environmental protests and macroeconomic indicators are combined with the EVS proceedings to produce a final dataset that is an unbalanced author-level panel.

2. 3. 2. Dependent Variables

Actors' incorporation of new institutional logics and technologies is measured from the EVS proceedings. I distinguish between the environmental and industrial logics by using session themes to which an author's paper belongs, and abstract and keywords from the author's paper. When abstract and keywords are not provided, the main content of a paper was examined. If a paper discusses environmental and ecological issues such as air and noise pollution, safety, human health, emissions, environmental impacts, sustainability, or fuel saving, I categorize the paper as an environmental logic. Thus a variable ENVIRONMENTAL LOGIC is coded as one if the paper covers an environmental logic; and otherwise is coded as zero (see Table 3 for the detailed coding framework). To validate the reliability of coding, I first randomly selected 100 articles. Two research assistants then independently coded the selected articles based on the coding framework. Average percentage agreement across three coders was 92 percent. Krippendorff's alpha was .83, which indicates excellent agreement by chance (Krippendorff 2004; Neuendorf 2002).

On the other hand, if a paper's main topic related to market strategies, standardization, techno-economic efficiency and performance, commercialization, and infrastructure, a variable labeled as INDUSTRIAL LOGIC is one; and zero otherwise. Similarly to the variable ENVIRONMENTAL LOGIC, I calculate average percentage agreement and Krippendorff's alpha across three coders. Average percentage agreement and Krippendorff's alpha were 94 percent and .71 respectively, which indicates good agreement by chance (Krippendorff 2004; Neuendorf 2002). When a paper considers issues that relate to both industrial and environmental logics, both INDUSTRIAL LOGIC and ENVIRONMENTAL LOGIC are coded as one.

*** Insert Table 3 about here ***

Similarly, the variable labeled as ELECTRIC DRIVE is coded as one if a paper's main topic of technology is related to the pure electric vehicle; and zero otherwise. A variable HYBRID DRIVE is coded as one if a paper discusses technology associated with the combination of internal combustion engine and electric motors or/and batteries; and zero otherwise. When both electric and hybrid drive is discussed in a paper, the variables ELECTRIC DRIVE and HYBRID DRIVE are coded as one.

*** Insert Table 4 about here ***

2. 3. 3. Independent Variables

Social movement activity, the variable ENVIRONMENTAL PROTEST, is measured as the total number of environmental protest events covered by the *New York Times* in a given year. Environmental protest events covered by the *New York Times* include both domestic and international protests associated with environmental pollution. Following the prior social movement literature (Earl, Martin, McCarthy, and Soule 2004; Earl and Soule 2006), I counted environmental protests events in which more than one actor participated at the public place. Labor-related events, lawsuits, letter-writing campaigns, environmental "teach-ins", public hearings and environment-related conferences are not included (see Earl and Soule 2006 for the detailed criteria).

Because it takes time to publish a research paper, contemporaneous environmental movements do not necessarily influence the topics of that year's research proceedings. It is thus important to identify the year when authors begin their research projects from which the research proceedings are published. In order to find the appropriate time lags, I first interviewed several conference participants who stated that the publication cycle in these engineering fields is within three years, in general, and that they submitted research proceedings to the international EVS within one or two years after the initial research project had begun. Given this understanding from the interviews, I used a series of lagged variables: one-, two-, three-, and four-year lags of ENVIRONMENTAL PROTEST. The results also show that the effects of three- and four-year lags on an author's incorporation of institutional logics and technologies are not statistically significant. Thus, I use a two-year lag of ENVIRONMENTAL PROTEST in all specifications.

In order to capture economic recessions, annual U.S. unemployment rates, labeled as US UNEMPLOYMENT, are collected from the database of the U.S. Bureau of Labor Statistics. Out of several macroeconomic indicators, unemployment rates are used to capture economic recessions for the following reasons. First, the unemployment rate is widely considered one of macroeconomic indicators capturing economic recessions. Moreover, unemployment rates are closely related to labor unions' activity. As discussed earlier, during economic recessions, industries influenced by stringent environmental standards lobbied for lowering environmental standards. In particular, labor unions in the automobile and steel industries joined these efforts, claiming that higher environmental standards increase cost pressure on business sectors, which results in large-scale layoffs. Thus, the unemployment rate will be a valid proxy for capturing the ebb and flow of the industrial logic. As in the case of ENVIRONMENTAL MOVEMENT, I use a two-year lag of US UNEMPLOYMENT.

Finally, to capture the degree of cohesion networks of the institutional logics, I calculate the network density of authors for each institutional logic (c.f., Burt 2005). If two authors coauthored a paper which incorporates an environmental logic in a given year, they have a direct environmental logic tie. These direct ties are used to calculate the network density within the environmental logic. The variable COHESION NETWORKS ENVIRONMENTAL LOGIC is defined as a total number of direct ties divided by maximum possible ties among authors in a given year.

Similarly, I calculate the density of co-authorship networks in the industrial logic. I define COHESION NETWORKS INDUSTRIAL LOGIC as the total number of direct ties scaled by maximum possible ties. Higher values of both measures represent stronger cohesion networks of the institutional logics.[2] As with ENVIRONMENTAL PROTEST and US UNEMPLOYMENT, two-year lags of COHESION NETWORKS ENVIRONMENTAL LOGIC and COHESION NETWORKS INDUSTRIAL LOGIC are used, because the strength of institutional logics may influence authors when they actually begin their research projects.

2. 3. 4. Control Variables

In addition to the main variables of interest, I include a set of control variables to account for potential alternative explanations. I first control for the prevalence of institutional logics that potentially influences actors' embracing of technologies (e.g.,

[2] Because the maximum values of the cohesion networks of both environmental and industrial logics are relatively small (.09 and .02 respectively), I multiply these scores by 1000 to make it easier to interpret the marginal effects.

Sine, Haveman, and Tolbert 2005). To do this, I first measure the size of both environmental and industrial logics by counting the total number of authors having incorporated each institutional logic in a given year. I then calculate change rates of those logics in a given year. As noted above, I use the two-year lags of Δ ENVIRONMENT LOGIC and Δ ENVIRONMENTAL LOGIC.

I also include authors' affiliations and home countries to control for institution-specific effects. Based on the information provided in the authors' biographies, I categorize authors' affiliations into five categories: universities, governments, government-sponsored research institutions, independent private research institutions and for-profit companies. To control for possible country-specific effects, I create dummy variables CANADA, CHINA, GERMANY, FRANCE, ITALY, JAPAN, KOREA, UK and US.

Average annual prices of gasoline, oil and internal combustion engine cars are collected from the U.S. Bureau of Economic Analysis and the U.S. Department of Energy. Internal combustion engine vehicles have been major competitors to electric and hybrid vehicles for more than a century (Kirsch 2000; Mom 2004; Sachs 1992). In particular, scholars have demonstrated that the prices of oil, gas and internal combustion engine vehicles appropriately capture the competitiveness of internal combustion engine vehicles such as quality, cost competitiveness and techno-economic efficiency (e.g., Rosen 1974). To account for substitution effects, I include the annual price changes of oil and internal combustion engine vehicles.[3] Variables Δ

[3] Because gasoline prices are highly correlated with oil prices, I include only one of the two variables in the specification. In lieu of gasoline price, I prefer including oil price, because oil price may influence other business sectors in which oil is a major input to produce their products and services and using oil price thus captures a larger-scale impact on actors' adoption of technology.

US OIL PRICE and Δ US CAR PRICE are defined as price changes scaled by the previous prices respectively. I also used two-year lags of Δ US OIL PRICE and Δ US CAR PRICE.

Finally, to control for unobserved heterogeneity and external shocks (e.g., Bresnahan 1987), I consider technology-fixed effects and time-fixed effects as controls in my specifications.[4] Performance of motors and electric storage batteries has been perceived as a major technical hurdle in developing electric and hybrid vehicles. Over the course of the study period, several new types of motors and electric storage batteries have been developed, and their respective advantages and disadvantages have been discussed in the EVS community. I include dummy variables of AC-, DC-, induction-, permanent magnet-, switched reluctance- and capacitor/flywheel- based motors to control for motor-specific effects. Likewise, to control for battery-fixed effects, I include dummies of lead acid, fuel cell, and lithium-, nickel- and zinc air-based batteries. Table 4 summarizes the definitions of variables described in this section.

2. 3. 5. Statistical Method

Because the dependent variables in this study are binary, I employ a probit regression model:

$$\Pr[y = 1 \mid x] = \Phi(x'\beta) = \int_{-\infty}^{x'\beta} \phi(z)dz \qquad (1)$$

[4] When year dummies are included in each specification, some year dummies are automatically excluded because of multicolinearity. As a result, each specification includes a different set of year dummies, depending on the multicolinearity between year dummies and yearly measured variables in the specification. Because the overall results with or without year dummies are consistent, and because each specification should have the same set of variables to compare the marginal effects across specifications, year dummies are not included in all reported specifications.

where $\Phi(\cdot)$ is the standard normal cumulative distribution function, $\phi(z)$, a first order derivative of $\Phi(\cdot)$ is the standard normal probability density function, y is a dependent variable, $\mathbf{x}$ represents a vector of explanatory variables, and $\boldsymbol{\beta}$ is a vector of coefficient estimates.

As expressed in equation (1), the probit model does not directly predict the probability of $y_i = 1$ but z_i which is then mapped to the probability of $y_i = 1$ in the standard normal cumulative distribution function. This feature makes it difficult to directly interpret the coefficients of the probit model (Cameron and Trivedi 2005; Greene 2003). I thus calculate the marginal effects, a partial derivative of the standard normal distribution function with respect to the mean of x_j. The marginal effect of x_j represents the magnitude of a probability change per unit increase in x_j at the point of its mean. Equation (2) formally represents the marginal effects calculated in this study:

$$\frac{\partial(y_i = 1 \mid x_i)}{\partial \bar{x}_{ij}} = \phi(\bar{x}_i^{'}\hat{\beta})\hat{\beta}_j \qquad (2)$$

where $\bar{x}$ is a vector of the means of explanatory variables and $\hat{\beta}$ is the predicted value of coefficient estimates.

2. 4. Results

2. 4. 1. Descriptive Statistics and Correlations

Table 5 presents the descriptive statistics and correlations. The means of environmental logic and industrial logic are .37 and .94, showing that around one third of authors incorporate the environmental logic and that a majority of authors incorporate elements of the industrial logic. Thirty-one percent (= .37 + .94 - 1) of authors incorporate both environmental and industrial logics in their papers. Interestingly, COHESION NETWORKS ENVIRONMENTAL LOGIC is double that of COHESION NETWORKS INDUSTRIAL LOGIC, indicating that *prima facie* the cohesion networks of the environmental logic group is stronger than that of the industrial logic. With regard to vehicle types, 38% of authors discussed hybrid drive whereas 71% of authors have written papers related to pure electric drive. Nine percent of authors have discussed both electric and hybrid drive (= .38 + .71 - 1).

*** Insert Table 5 about here ***

As I hypothesized, the results of bivariate correlations show that ENVIRONMENTAL PROTEST is positively related to ENVIRONMENTAL LOGIC but is negatively related to INDUSTRIAL LOGIC. Conversely, US UNEMPLOYMENT is negatively related to ENVIRONMENTAL LOGIC while positively related to INDUSTRIAL LOGIC. As for the relationships between the degree of cohesion networks of logics and actors' acceptance of vehicle types, the results indicate that the degree of cohesion networks of both logics is positively associated with ELECTRIC DRIVE while negatively associated with HYBRID DRIVE. Since these are bivariate correlations, which do not consider other control variables that potentially and simultaneously influence these relationships, I exercise caution in interpreting these results and therefore turn to multivariate regression analyses to better understand the hypothesized causal relationships.

2. 4. 2. Regression Results

Table 6 presents the results of the probit regressions in which I test hypotheses 1a, 1b, 2a and 2b. In models 1 and 2 I test the effects of environmental protests and unemployment rate on an actor's incorporation of an industrial logic. In model 1 I include control variables only. While authors from most countries are positively concerned about an industrial logic, authors from Canada are less likely to consider the industrial logic in their papers. Interestingly, authors from China, a major emerging economy, show the strongest country effect on the incorporation of an industrial logic. With respect to institution-specific effects, not surprisingly, authors from the industry sectors are most likely to incorporate an industrial logic, whereas government officials are least likely to discuss an industrial logic. An increase in CO_2 emissions is negatively associated with an actor's incorporation of an industrial logic.

*** Insert Table 6 about here ***

In model 2 I include two-year lags of ENVIRONMENTAL PROTEST and US UNEMPLOYMENT. Hypotheses 1b and 2b posit that environmental protests (economic recessions) in the sociocultural arena will decrease (increase) the likelihood of an actor's incorporation of an industrial logic. As I hypothesized, the results show that environmental protests negatively and significantly influence an actor's incorporation of an industrial logic ($\beta = -.008$; $p < .01$), while the effect of unemployment rates is positive and significant ($\beta = .048$; $p < .05$). Thus, hypotheses 1b and 2b are supported. In order to interpret the magnitude of probability changes, I calculate the marginal effects and report them in the column next to the coefficients. The results show that one unit increase in ENVIRONMENTAL PROTEST will decrease the probability of an actor's incorporating an industrial logic by .001 and that one unit increase in US UNEMPLOYMENT will increase its probability by .005.

In models 3 and 4 I include the same set of explanatory variables and predict the probability of an actor's incorporating an environmental logic. Model 3 shows the results with only control variables included. Unlike the results in model 1, authors from most countries are less likely to discuss environmental issues. Interestingly, only authors from Italy are more likely to incorporate an environmental logic. Canadian authors (who showed a negative propensity to incorporate an industrial logic) are more likely to incorporate an environmental logic, although the effect is not significant. Government officials and researchers from the independent private research institutions are most likely to discuss the issues associated with an environmental logic. While an increase in U.S. passenger car prices is negatively and significantly related to an actor's incorporation of an environmental logic, the effect of an increase in U.S. oil prices is positive.

In model 4 I include the variables ENVIRONMENTAL PROTEST and US UNEMPLOYMENT to test hypotheses 1a and 2a, suggesting a positive relationship between environmental protests and an actor's incorporation of an environmental logic; and a negative relationship between economic recessions and an actor's incorporation of an environmental logic. The effect of ENVIRONMENTAL PROEST is positive but not significant ($\beta = .002$; $p > .10$). Hence, hypothesis 1a is not supported. However, US UNEMPLOYMENT is negatively and significantly associated with an actor's incorporation of an environmental logic ($\beta = -.046$; $p < .01$), which supports hypothesis 2a. The marginal effect of US UNEMPLOYMENT indicates that one unit increase in the unemployment rate will decrease the probability of an actor's incorporating an environmental logic by .017.

In Table 7 I test hypotheses 3 and 4, positing the relationships between the degree of cohesion networks in logics and an actor's acceptance of vehicle types. In addition to the control variables included in the previous regressions, I further include technology fixed effects and institutional logic effects as control variables, which potentially influence an actor's acceptance of technologies.

*** Insert Table 7 about here ***

Model 5 includes control variables and predicts the propensity of an actor's embracing of ELECTRIC DRIVE. In general, authors from most countries, except for Japan, are less likely to discuss electric drive. Governmental officials show strong interests in pure electric drive. An increase in oil price is negatively related to an actor's embrace of electric drive, but an increase in passenger car price is positively related to an actor's embrace of electric drive. A higher level of CO_2 emissions tends to increase the likelihood of an actor's embrace of electric drive. DC MOTOR, FUEL CELL BATTERY, LEAD ACID BATTERY, and ZINCAIR-BASED BATTERY are positively associated with ELECTRIC DRIVE. Interestingly, Δ ENVIRONMENTAL LOGIC is positively related to ELECTRIC DRIVE whereas Δ INDUSTRIAL LOGIC is negatively related to ELECTRIC DRIVE.

In model 6 I include variables of COHESION NETWORKS ENVIRONMENTAL LOGIC and COHESION NETWORKS INDUSTRIAL LOGIC to test hypotheses 3 and 4 in which I expected that the strong cohesion networks of an environmental (industrial) logic increase (decrease) the likelihood of an actor's embracing of electric drive. As I predicted, the results show that the effect of COHESION NETWORKS ENVIRONMENTAL LOGIC is positive and significant ($\beta = .039$; $p < .01$) and that the effect of COHESION NETWORKS INDUSTRIAL LOGIC is negative and significant ($\beta = -.072$; $p < .01$). The marginal effects of these two variables are .013 and -.023 respectively, indicating that one unit increase in the cohesion networks of an environmental logic will increase the probability of an actor's discussing electric drive by .013; but one unit increase in the cohesion networks of an industrial logic will decrease its probability by .023. These results support hypotheses 3 and 4.

To test hypothesis 5 in which I posited that an actor will be more likely to embrace hybrid drive when both institutional logics are highly cohesive, in model 8 I first include the same set of variables as those in model 6 and predict the probability of an actor's embracing hybrid drive. The results show that COHESION NETWORKS ENVIRONMENTAL LOGIC is negatively associated with HYBRID DRIVE, but COHESION NETWORKS INDUSTRIAL LOGIC is positively related to HYBRID DRIVE.

To further explore the joint effect of the cohesion networks of two logics, I split the sample into two groups by using the median of COHESION NETWORKS ENVIRONMENTAL LOGIC.[5] Table 8 presents the results. In the case of high COHESION NETWORKS ENVIRONMENTAL LOGIC the effect of COHESION NETWORKS INDUSTRIAL LOGIC is negative and significant ($\beta = -.090$; $p < .01$). However, in the case of low COHESION NETWORKS ENVIRONMENTAL

[5] I also conducted the different subsample splits by using the mean and quartiles. The results are consistent with those reported herein.

LOGIC, I find a positive and significant relationship between COHESION NETWORKS INDUSTRIAL LOGIC and HYBRID DRIVE ($\beta = .807$; $p < .01$). I also conduct a t-test of marginal effects of COHESION NETWORKS INDUSTRIAL LOGIC across models 9 and 10. The difference in marginal effects is significant at the .01 significance level. These results together indicate that when the industrial logic group is more cohesive but the environmental logic group is less cohesive, actors are more likely to embrace hybrid drive, which refutes my hypothesis 5.

*** Insert Table 8 about here ***

2. 4. 3. Sensitivity and Robustness

To assess the sensitivity and robustness of the results, I tested several different models.[6] One of the critical issues is how to control for endogeneity when multiple binary outcome models are used. If one binary outcome is a function of the other binary outcome, and if this endogeneity is not taken into account, then the results may be biased. In this study, if an actor's incorporation of a certain type of an institutional logic systematically influences the actor's choice of topics associated with electric or hybrid drive, the omission of the variables ENVIRONMENTAL LOGIC and INDUSTRIAL LOGIC in the right hand side of the equation in models 5-10 will lead to biased coefficient estimates. Two lines of discussion have emerged to take into account this sort of endogeneity (Maddala 1986). One line of research focuses on whether Heckman's two-step approximation or least-squares approximation (i.e. 2SLS and 3SLS) can be applied to the case in which the dependent variables are all

[6] All results discussed in the section are available from the author upon request.

binary outcomes. Van de Ven and Van Praag (1981) demonstrate that the Heckman's two-step procedure can work well in the case of the bivariate probit model with sample selection, if the heteroscedasticity is appropriately corrected. Furthermore, Wilde (2000) suggests that Heckman's two-step approximation can be applied to the multivariate probit model. However, correction of heteroscedasticity is still an important issue to be solved in this case (Bhattacharya, Goldman, and McCaffrey 2006). Another line of research suggests a multivariate probit model, by using a Geweke–Hajivassilou–Keane simulator to take into account the correlation among error terms across probit equations (e.g., Geweke, Keane, and Runkle 1994; Jenkins, Cappellari, Lynn, Jäckle, and Sala 2006). A multivariate probit model has been commonly used in the case of multiple binary outcomes (e.g., Ingram, Yue, and Rao 2010; Jenkins, Cappellari, Lynn, Jäckle, and Sala 2006). Table 9 presents the comparison between the results from multivariate probit models and those from univariate probit models. Overall results are consistent.

*** Insert Table 9 about here ***

Another important issue is the existence of unobserved factors, which may influence actors' choice of topics associated with logics and technologies. I additionally ran conditional logit regressions, by which I control for author-specific unobserved factors. There is only limited variation among demographic factors, resulting in the sample size being reduced to around 3,000. However, overall results were consistent with those reported herein.

Third, market demand effects such as commercial success or failure and consumers' preferences may influence technologists' incorporation of a technology agenda. The General Motors *EV1* pure electric vehicle was launched in the US market on December 2, 1996. The Toyota *Prius* and Honda *Insight* hybrid vehicles were first introduced in Japan in 1997 and 1999, and later in the US market in 1999 and 2000, respectively. To account for the demand-side effects, I dropped the observations from 2001 to 2009 and re-ran the same regressions reported in this study.[7] Overall results are consistent with those reported herein.

Fourth, social movement activity and actors' incorporation of logics and technologies may also be influenced by political conditions. To control for this, I included the variable representing political regimes—democratic versus republican administrations. Interestingly, during the democratic administration, electric technologists are more likely to incorporate an environmental logic but less likely to incorporate an industrial logic. Furthermore, the results show that during the democratic administration, actors tend to support pure electric vehicles rather than hybrid vehicles. Despite the inclusion of political conditions, overall results remain consistent.

Finally, due to data availability, I used U.S.-based macroeconomic variables to capture unemployment rates, oil and car prices, and CO_2 emissions, assuming that the U.S. economy and pollution levels are equivalent with overall patterns of world economies and pollution levels. In order to check the viability of using U.S.-based variables as proxies for capturing world-level economies and pollution, I tested the same models reported in this study with only U.S. authors and domestic

[7] Because I use two-year lags of the yearly measured variables, I dropped the observations from 2001 to 2009, which controls for the demand-side effects starting from 1999.

environmental protests included. The results are consistent with those of the full sample.

The results of these robustness checks demonstrate that the findings presented in this study are not merely driven by the unique characteristics of the statistical methods or data. Rather, they show that there are significant effects of social movements and economic recessions on an actor's incorporation of logics. Moreover, the results suggest that institutional logics, more precisely cohesiveness among actors in institutional logics, substantially influence the differential evolution of electric and hybrid drive.

2. 5. Discussion

In this study I seek to explore the social and institutional processes shaping differential technology development. Combining the social movements and institutional logic arguments, I argue that an institutional logic is a product of actors' collective actions, and that institutional logics can systematically determine differential trajectories of technology development. To test my arguments, I examine the processes of technology and logic construction in the international arena of electric vehicles from 1969-2009. I find that environmental protests have a negative effect on an actor's incorporation of an industrial logic; whereas high unemployment rates have a positive effect on it. In addition, I find that high unemployment rates preclude an actor's incorporation of an environmental logic. These empirical findings suggest that environmental movements and economic conditions are closely related to competition in institutional logics within the technological sphere.

I further find that the strength of actors' beliefs in a given logic—operationalized as coauthorship density—systematically influences differential developmental trajectories of new technologies. That is, the strong cohesion networks of an environmental logic positively influence an actor's choice of topics associated with electric drive; whereas those of an industrial logic negatively influence an actor's embrace of electric drive. As opposed to my prediction, I find that discussion of hybrid drive has become prevalent when the strength of an industrial logic is high but that of an environmental logic is low. This result suggests that the emergence of hybrid drive may not be an outcome of the hybridization of two competing logics. Rather, it may be that hybrid drive emerges as a result of the dominance of an institutional logic.

This study has several theoretical implications. First, this study bridges the gap between the social movements and institutional logic literatures, suggesting that institutional logics can wax and wane, depending on social and economic conditions, although they persist and continue to influence actors. Institutional logics are endogenous. Social actors collectively create a new logic or provide different meanings with the existing logics. Examination of this process in this study helps us better understand the origin and development of institutional logics.

Second, this study contributes to the extant technology literature in that it examines social and institutional processes shaping technology development. The extant technology literature largely focusing on techno-economic influences on technology development is somewhat limited and incomplete, because technology development is indeed a multiple and dynamic social phenomenon. The findings in this study provide a better understanding of why certain technologies become dominant but others limp along or disappear. This study shows that social movements and economic conditions indirectly shape the process of technology construction in the technological community, and that degree of cohesiveness among actors' logics is closely associated with the emergence or decline of technology.

Third, this study extends the existing entrepreneurship literature. The existing entrepreneurship literature suggests that introduction of new technology not only fosters competition in technologies, but also creates framing conflict in actors' interpretations associated with the meaning and value of the new technology (Barley 1986; Bijker 1987). Munir and Phillips (2005) further demonstrate that new technology often creates new social roles and shapes actors' life styles. What is missing is where new technology comes from. This study shows how social and institutional forces systematically influence technological trajectories, prior to the introduction of the product to the market.

In addition to the theoretical contributions, this study has several practical implications. First, this study suggests that entrepreneurial success in the technological field is not merely attributed to a single entrepreneur or a single firm. Rather, it involves a larger scale commitment of actors in different institutional fields. Thus, when managers or entrepreneurs intend to introduce new technology, it is important to trace current socio-economic trends, values, dominant logics, lifestyles and even abstract-level ideology.

Second, this study highlights the openness of technology development. Building technological capabilities may be necessary but may not be sufficient. It shows that logic contestation, particularly the strength of logics, is closely related to differential trajectories of technology development. Attention to institutional logics within the technological community may be essential for future technological success.

Finally, this study shows the importance of managing institutional logics. Although institutional logics serve as a critical determinant of future trajectories of technology development, institutional logics are not merely exogenously given. It is social actors who collectively and strategically mobilize resources and manage institutional logics.

While this study has several important theoretical and practical implications, I acknowledge several caveats of this study and thus provide avenues for future research. First, this study primarily focuses on actors' discussion of technology in the professional society of electric and hybrid vehicles. Thus, this study does not incorporate consumers' logics which may potentially influence technological evolution. A possible extension of this study would explore what are consumers' institutional logics associated with automotive technology, and how the consumers' logics influence technological evolution.

Second, I focus on a single conference in the community of automotive technologists. Although the EVS is one of the most established and legitimate international conferences, I do not know whether my findings necessarily generalize to other automotive conferences.

Finally, because the context of this study is the emergence of automotive technology, I do not know whether my findings can be applied to the emergence of other types of technology. I am thus cautious to generalize my findings to other technological contexts. Corroboratory research in different technological contexts would strengthen my arguments.

Technological evolution has been widely examined in the fields of organization theory and strategy. This study contributes to the existing literature by exploring endogenous social and institutional processes influencing technological evolution. Importantly, I bridge the gap between social movements and institutional logic literatures, to better understand the complex phenomenon of technological development. Empirical evidence suggests that social movements and economic conditions influence logic competition within the technological community. The findings also emphasize the role of institutional logics in the emergence and decline of technology within a particular setting.

Chapter 3: Tracing the Evolution of Institutional Logics in the Electric Automotive Community

In this chapter I explore how social actors faced with multiple and conflicting institutional logics manage multiple institutional logics. While much of institutional work has suggested and empirically demonstrated that institutional logics shape cognitive and behavioral patterns of actors, what still remains unanswered is how actors collectively construct the meanings of institutional logics when facing competing institutional logics. Borrowing from the perspectives of institutional logics and collective actions, I argue that actors strategically create new meanings, modify a current institutional logic, and reinforce the new meanings rather than passively adopting institutional logics.

To trace temporal changes in meanings which constitute competing institutional logics, I conduct an inductive study, employing computer-aided text analysis. Using research proceedings published by the international *Electric Vehicle Symposium* in 1969 and 1994, I found four social mechanisms of logic construction: *clarifying*, *patching*, *expanding* and *reinforcing*. Moreover, empirical findings suggest that the social mechanisms of *patching, expanding* and *reinforcing* are closely related to the emergence of hybrid drive.

This study directly enriches the existing institutional logic literature in that it empirically demonstrates how institutional logics are constructed over time, rather than remaining stable and unidirectionally influencing behavior and cognition of actors. Another important contribution is that this study shows how actors collectively and purposefully shape and are shaped by the evolution of institutional logics. Thus, the results address a long-standing theoretical tension between dualism and duality in organizational sociology, by identifying middle-range social mechanisms which together influence both structure and agency. Finally, this study contributes to the current technology literature, by showing how actors can collectively determine future developmental trajectories of new technologies via the social construction of institutional logics.

3. 1. Introduction

Institutional change is a social phenomenon that institutional scholars have long sought to understand (Scott, Ruef, Mendel, and Caronna 2000; Tolbert and Zucker 1983). Early work on institutional change has suggested that external shocks and techno-economic needs foster deinstitutionalization (Fligstein 2001; Oliver 1992; Tolbert and Zucker 1983). Some scholars in the organizational strategy field develop a view of strategic actions that emphasizes organizational variations under institutional pressures (Elsbach 1994; Oliver 1991; Fligstein 2001; Suchman 1995; Seo and Creed 2002). More recently, institutional scholars have begun to focus on the interplay between actors and institutions, and they are paying more attention to cognitive and cultural processes influencing creation, development and diffusion of practices within the institutional field (Zietsma and Lawrence 2010; Zilber 2002; 2006).

Relatedly, scholars have revisited the notion of “institutional logics” and seek to understand their roles in institutional change (e.g., Thornton 2002). Institutional logics are collective belief systems that shape cognitive and behavioral patterns of actors (Friedland and Alford 1991; Thornton and Ocasio 2008). Institutional logics provide actors with rules and principles through which actors makes sense of institutions (Thornton 2004). Borrowing from the institutional logic perspective, a body of studies on institutional logics has found structural outcomes of institutional logics (e.g., Greenwood, Díaz, Li, and Lorente 2010; Lounsbury 2007; Marquis and Lounsbury 2007; Thornton 2002). However, much of empirical work still revolves around the unitary isomorphism argument emphasizing institutional pressures.

Alford and Friedland (1985) originally suggest that actors in modern society encounter multiple institutional logics, which often conflict with one another. Fundamental questions that as of yet remain unanswered are how individual actors manage these conflicting logics, whether institutional logics homogeneously influence actors' cognition and behaviors, and whether institutional logics can be shaped by actors. Answering these questions will help us to gain a better understanding of the social dynamics of institutional change.

Recent work, drawing upon the pluralistic view of institutional logics, has just begun to pay attention to the roles of actors in managing competing institutional logics, and shows the temporal fluctuation of institutional logics (e.g., Dunn and Jones 2010). Less is known about nuances and dynamics of processes of logic construction. The social constructivist view provides some theoretical mechanisms by which actors manage conflicting institutional logics. For example, Thornton and Ocasio (2008) argue that meanings of institutional logics are socially constructed. Actors purposefully enact their interpretations of institutional logics, develop shared understandings of institutional logics, and stabilize the new meanings. This subjective view of institutional logics implicitly suggests that actors can change existing institutions, or at least the meanings of institutions, through the mechanism of logic construction, highlighting the roles of actors in institutional logics. Other scholars have paid attention to collective actions as a source of creating a new institutional logic (for a review see Fligstein and McAdam 2011).

Although fundamental, our understanding of creation, development and transformation of institutional logics is largely understudied. In particular, less is known regarding the process of framing the meanings of institutional logics. Moreover, when it comes to technology development, we know little about how or whether institutional logics can shape technology development. Recent technology literature has begun to underscore the role of institutional logics in technology development (Kaplan and Murray 2010; Kaplan and Tripsas 2008). However, empirical work is yet limited.

The purpose of this study, therefore, is to explore how actors in a technological community mobilize multiple and conflicting institutional logics, and how the different construction of institutional logics shapes technological development. I specifically focus on the technological discourse about electric and hybrid drives in the international *Electric Vehicle Symposium*. I have chosen this technological context partly because automobile industries have been closely associated with multiple institutional fields in general, partly because multiple technologies (i.e. pure electric, hybrid, and internal combustion engine vehicles) have been long competing with one another, and partly because social groups with different cultural perspectives substantially engage in discussing benefits and costs of competing technologies. Therefore, it would be an interesting empirical setting where I can explore the sociocultural complexity and dynamics among actors, institutional logics and technologies.

In order to trace meanings of institutional logics, I conducted an inductive study based on the history of electric vehicles and keyword-based, computer-aided text analysis. I identify two competing institutional logics (Environmentalism vs. Industrialism) impacting this technological community. I then trace how technologists in EVS mobilize the two institutional logics over time. Using research proceedings published by the EVS in 1969 and in 1994, I found four social mechanisms of constructing institutional logics: *clarifying*, *patching*, *expanding* and *reinforcing*. I further found that mechanisms of *patching*, *expanding* and *reinforcing* are closely related to the emergence of hybrid drive within the community of electric vehicle researchers.

3. 2. Institutional Logics and Evolution of Electric/Hybrid Drives

3. 2. 1. Environmental Logic and Industrial Logic

Since the Industrial Revolution, an industrial logic has long dominated industrial society. Actors believe that economic growth can provide jobs, entrepreneurial opportunities and economic wealth for the society (Hays 1995). A series of relevant technological innovations resulted in the invention of new machines and the development of sophisticated mass production systems which replaced the dependence of labor on humans and animals. Continuous technological improvements in production systems allowed for more products and more consumption, which in turn required exploiting more natural resources. Industrialization resulted in the pollution of air, soil and water. In her classic book, *Silent Spring*, Rachel Carson (1962) describes how these industrial processes damaged environments in the 1950s and suggests demands for ecologically sustainable economic growth.

In the 1950s and 1960s, agendas of social movements, rooted in political liberalism, revolved around income inequality, gender/race discrimination and civil rights (Isserman and Kazin 2004). As environmental pollution increasingly became a critical social issue, environmental protection was incorporated into the agenda of 1960s social movements (Gottlieb 2005; Pepper 1996). These actors sought to protect air, water, soil and wetlands from pollution and economic development, promote recycling, and support alternative energy. Grassroots environmental movements facilitated the expansion of social movement organizations supporting environmental protection (Pepper 1996).

Gradually, these environmental movements stimulated an environmental logic highlighting the preservation of natural environments and the co-prosperity of humans and non-humans. Since the Industrial Revolution, an industrial logic has prevailed that regards technological innovation as positive economic and social progress (Shrivastava 1994). However, the emergence of an environmental logic has changed actors' attitudes toward technology. Actors had begun to pay attention to the negative impact of technology and industrialization. These countermoves resulted in political successes such as passage of the Clean Air Act and creation of the Environmental Protection Agency in the 1970s. Environmental regulations include strict requirements, standards, technical measurements of hazardous technology, safety, and human health, all of which brought about a new agenda of ecologically sustainable economic development. An increase in environmental awareness throughout the 1960s, 1970s, and 1980s widely influenced technological fields where scientists, engineers and technical policymakers had begun to turn their attention to the relationship between technology and society.

3. 2. 2. Evolution of Electric and Hybrid Drive

In response to environmental movements, technologists revisited alternative fuel vehicles, including electric vehicles, from which they could dramatically cut hazardous emissions. In the 1880s, multiple automotive technologies such as gasoline-based (internal combustion) and steam-based (external combustion) engines and electric motor-based vehicles were introduced and competed with one another (Hoffman 1967; Kirsch 2000; Mom 2004). The original idea of hybrid vehicles combining the internal combustion-engine with an electric motor to improve vehicle performance was also introduced in the United States in 1905 when American engineer Henri Pieper filed for a patent.[8] Several hybrid vehicles, such as a Woods Dual-Power gasoline and electric model, were produced and commercially available in the Unites States in the early 1900s.

By the end of the First World War, gasoline-based internal combustion engine cars had become a dominant design (see Kirsch 2000 for the detailed historical discussion). Relatedly, an industrial logic representing techno-economic efficiency and efficient use of natural resources came to dominate the community of automotive

[8] In 1901, Ferdinand Porsche first introduced *Lohner-Porsche Mixte Hybrid*, a 4WD series-hybrid version of vehicles in Germany.

technologists, which strongly supported gasoline-based internal combustion engine cars.

Social movements in the 1960s increased regulatory pressure and led electric scientists, engineers, industrial professionals and technical policymakers as well as environmental groups to again turn their attention to electric vehicles. As a part of these efforts, a group of electric scientists, engineers and technical policymakers founded an electric vehicle forum, called the International Electric Vehicle Symposium (EVS), in 1969.

When the symposium was first formed, scientists and technologists were optimistic about the future of electric vehicles, partly because environmental activists and some policymakers strongly supported electric vehicles, and partly because electric engineers were confident about improving battery performance, which had long been a critical issue for the performance of electric vehicles (Wouk 1986). The following excerpts from the EVS proceedings in 1971 aptly illustrate technologists' optimism about electric vehicles in the early 1970s.

> When the president of a major oil company predicts, as the president of Shell Oil Company predicted about a month ago, that there will be **five million electric cars** in operation in this country **in 1985**, you know that progress has been made. (Lucking 1971, p 5)

> "[We] might expect **by 1985 something like 25 to 30 million vehicles capable of electric propulsion** at least when cruising on guideways. And the growth in all-electric vehicles would be less impeded by on-board energy storage limitations. (Weldon 1971, p. 14)

> … The performance of the electric cars which will have to replace gasoline-driven cars need not be inferior to those of gasoline-driven

> cars of the 1970's. An [electric] car in 1970, could reach **60 mph** and had **a range of 70 miles**. … **an [electric] car with a performance near to that of a gasoline-driven car has already been achieved**. (Bockris 1971, p. 18)

While the creation of the EVS was partly motivated by the goal of environmental protection, an environmental logic was not clearly accepted as an "institutional logic" within this technology community in the 1960s and 1970s. The primary concern of electric scientists was whether the electric vehicle was a viable alternative to gasoline-based internal combustion vehicles. The electric scientists believed that if they could improve battery power and motor speed, electric vehicles would soon replace internal combustion engine vehicles. Therefore, in 1969 most discussions centered on the technical performance of electric vehicles. In other words, technical discussions still revolved around an industrial logic, neglecting an environmental logic. Over the course of 40 years after the creation of the EVS, the ebb and flow of social movements systematically influenced technologists' incorporation of an environmental logic. Scientists and engineers had begun to provide their own interpretations of an environmental logic, by clarifying and elaborating the concepts of the environmental logic within the technological community. This social dynamic has deeply influenced the technical discourse associated with different types of vehicles.

Figure 5 presents a total number of papers, topics of which are either pure electric or hybrid vehicles in 1969 and in 1994. It shows that while only one paper discussed hybrid vehicles in 1969, 28 papers covered hybrid vehicles in 1994.

*** Insert Figure 5 about here ***

In Chapter 2 I argued that an institutional logic is one of the critical antecedents determining the emergence and decline of electric and hybrid drives. Further, I empirically demonstrated that the emergence of hybrid vehicles is an outcome of the dominance of an industrial logic. The results indicate that while an environmental logic firmly buttressed pure electric vehicles, an industrial logic strongly supported the emergence of hybrid vehicles.

Empirical evidence in Chapter 2 notwithstanding, we must still explain how technologists mobilize the meanings of environmental and industrial logics. How did an environmental logic not become a dominant logic, thereby providing potential for the emergence of hybrid vehicles? How did an industrial logic become a dominant logic and strongly support the emergence of hybrid drive? The underlying assumption throughout the studies in this dissertation is that an institutional logic is neither stable nor enduring. It is plausible that although an institutional logic does exist over time, actors' interpretations of its meaning may change over time (c.f., Carlson 1994). Thus, it is important to understand how the subtle nuances of meanings of institutional logics change over time, in order to better understand the social dynamics of institutional and technological change.

3. 3. Method

Since I need to trace temporal semantic changes in the conceptual elements of institutional logics in the technology field, I employ keyword-based, computer-aided text analysis. A number of researchers have used this method to calculate the distance of meanings (e.g., Jones and Livne-Tarandach 2008; Kanbanoff 1997; Ruef 1999).

The underlying assumption of this analysis is that social conflicts in institutional logics pertaining to technology trigger actors' discourse and that discourse is often manifested in the form of texts (Phillips, Lawrence, and Hardy 2004). Thus, textual analysis has been used as an instrument to capture temporal changes in the meanings of institutional logics. I shall discuss the data and method in greater detail in the following sections.

3. 3. 1. Data

The technological community has been recognized as an important source of innovation, and research proceedings have thus been employed to understand the origins of technology development by a number of scholars (e.g., Fleming and Waguespack 2007; Lampel and Meyer 2008). I specifically focus on the electric vehicle conference EVS. Motivated by environmental movements and increasingly stringent emission policies, a group of scientists and engineers, policymakers and industry professionals needed to organize a forum where scientists, engineers, industry professionals and government could share technical information associated with electric motor technology.

As a result, the first EVS was held in Phoenix, Arizona in 1969. As of 2011, this symposium continues to expand globally and plays a critical role in introducing state-of-the-art technologies associated with electric-based transportation into markets worldwide. The EVS takes place biennially (yearly since 1996) and publishes research proceedings. As of 2009, 24 EVS proceedings have been published. Each includes research papers, names of authors, authors' affiliations and their country of origin, board of directors, organizing committees, and sponsors. I analyze the research proceedings published by the EVS in 1969 and in 1994 for the following reasons.

First, I chose this electric vehicle conference over other automobile conferences as a primary empirical setting because one of the goals of electric vehicle conferences is to introduce environmentally friendly vehicles. Therefore, it would be more instrumental to trace contestation between environmental and industrial logics in the electric vehicle community than in the setting of the traditional international combustion engine community where an industrial logic may primarily dominate.

Second, out of several local electric vehicle conferences, I select the EVS because this conference is one of the well-established and legitimate conferences among electric vehicles researchers. Moreover, unlike other regional conferences, the EVS is an international conference. Conference participants consist of engineers, scientists, industries and policymakers from various countries. Thus, technology, technical policy and environmental discussions are not limited to regional social, political and economic issues. Rather, they tend to cover global technical trends, country-level technological and policy implications, and global environmental issues. In the EVS, scientists, engineers, industry professionals and policymakers collectively introduce new concepts of electric automotive technology, and they develop shared understandings of various technologies, such as electric and hybrid drives, auxiliary components, chargers, charging infrastructure, and marketing and commercialization efforts.

Finally, out of 24 volumes of proceedings, I selected two proceedings published by the EVS in 1969 and in 1994. The research proceedings in 1969 allow me to capture the initial conceptual map of environmental and industrial logics. In particular, it helps to gain an understanding of the initial interpretations of each institutional logic developed throughout the course of the 1960s.

Since the 1969 EVS proceedings, global economies experienced two oil crises in the 1970s, which created increasing demand for alternative fuel vehicles, including purely electric vehicles. However, during this period, industry associations and labor unions raised their voices, criticizing environmental idealism. An industrial logic, the primary concerns of which are techno-economic efficiency and economic costs, drew attention to technologists and consumers. Ironically, these counter-movements suppressed actors' incorporation of an environmental logic, which hindered further development of electric vehicles.

Automakers lobbied for weakening stringent emission policies, despite strong opposition from environmental groups. While lobbying for postponing emission standards, automakers dramatically improved fuel efficiency of their internal combustion engine vehicles in order to meet the new emissions standards. As a result, automakers improved average fuel efficiency from 14 mpg to 22 mpg in 1981 (Anderson and Anderson 2010). These countermoves together stalled the further progress of electric vehicles in the 1980s.

In 1993 the Partnership for a New Generation of Vehicles (PNGV) initiated by the Clinton administration facilitated the development of electric and hybrid vehicles. The big three automakers (Chrysler, Ford and GM), the United States

Council for Automotive Research (USCAR), the Department of Energy, and other governmental agencies participated in this program. With the support of the PNGV, GM introduced its first purely electric vehicle, *EV1* in 1996, followed by Ford *Th!nk* in 1999. However, both *EV1* and *Th!nk* were completely discontinued in 2002 in the US markets. Unlike US automakers, Japanese automakers first introduced hybrid vehicles. Toyota launched its first hybrid vehicle, *Prius* using both internal combustion engine and electric motors in Japan in 1997, followed by the Honda *Insight* in 1999.

In order to account for the effects of the PNGV and commercial success or failure of electric and hybrid vehicles in the technology community, I selected research proceedings published in 1994. According to the interviews with conference participants, on average, it took two years for authors to submit their research papers to the EVS after they embarked on research projects. Thus, the 1994 proceedings tend to reflect technical and institutional contexts prior to the year 1992. Therefore, the selection of the 1994 proceedings can help to control for the potential effects of public programs or commercialization efforts in the 1990s, while still substantially encapsulating the temporal changes in technologists' responses to environmental and industrial logics.

3. 3. 2. Analysis

In order to trace changes in meanings associated with environmental and industrial logics, I employ a keyword-based, computer-aided text analysis. Because I deal with large volumes of texts, traditional, manual textual analysis is almost impossible. Employing computer-aided text analysis (CATA) allows for processing such large volumes of data. Additionally, the use of CATA helps reduce coding errors, in comparison with human coding, and eventually increases reliability (Kabanoff 1997; Krippendorff 2004).

I first develop a coding framework which consists of keywords or basic concepts associated with environmental and industrial logics (c.f., Abrahamson and Eisenman 2008; Abrahamson and Fairchild 1999). The environmental logic includes environmental issues such as pollution and environmental impacts. The concept of pollution represents the level of air and noise pollution which resulted from the internal combustion engine, as well as hybrid and pure electric vehicles. The concept of environmental impacts captures how much the use of a certain vehicle improves or pollutes the environment. Keywords for pollution are “air pollution”, “noise pollution”, “air quality”, etc. Environmental impacts include “environmental benefits”, “air quality improvement”, “emission level”, etc.

In contrast, the industrial logic includes the concepts of technical performance, economic benefits and costs, market strategies, infrastructure, and policy (see Table 3 for a detailed coding framework). The concept of technical performance reflects economic efficiency and the technical instrumentality of technologies. The concept of economic benefits and costs refers to benefits and costs of producing and purchasing electric and hybrid vehicles. Market strategies represent commercialization efforts and creation of markets for electric and hybrid vehicles. Infrastructure refers to physical facilities and financial/human/social capitals supporting technologies. The concept of policy refers to governmental policy and regulations associated with electricity and hybrid drives.

For example, keywords capturing the concept of technical performance include “power”, “speed”, “driving range”, “energy efficiency” and “time”. Keywords for economic benefits and costs include “revenue”, “profit”, “cost”, etc. Examples of market strategies consist of “commercialization”, “consumer needs”, or “market demand”. Keywords representing infrastructure are “road system”, “battery charging facility”, etc. Examples of keywords associated with policy are “legal requirements” and “traffic-related regulations”.

Based on this coding framework, I categorize research papers into two groups: environmental logic and industrial logic. Once I categorize research papers into two institutional logics, I calculate the frequency of keywords from the two groups of institutional logics in each year, following the procedure used by Wade, Porac, and Pollock (1997). The frequency of the keywords in each time period represents the prevalence of concepts of institutional logics in a given year (Kennedy 2008; Zelner, Henisz, and Holburn 2009). This process allows me to trace temporal changes in technologists’ interpretations of both institutional logics.

Based on the keywords identified, I trace all the sentences which contain those keywords. For example, if a sentence contains the word “speed”, I code the sentence “speed”. If one sentence contains multiple keywords, I put multiple codes into the sentence. I then calculate co-occurrence of codes in the same paragraph, using Jaccard coefficients. Calculation of Jaccard coefficients is as follows:

$$s_{ij} = \frac{p}{p+q+r}$$

where p = number of paragraphs where both codes i and j occur

q = number of paragraphs where code i occurs but code j does not occur

r = number of paragraphs where code i does not occur but code j occurs.

The underlying idea of this measure of similarity is that if two codes co-occur in the same paragraph, the concepts of the two codes are more semantically similar to each other than to those occurring in other paragraphs. From the Jaccard's similarity measures, I conducted a cluster analysis and finally created MDS (Multi-Dimensional Scale) maps which capture temporal changes in institutional logics.

3. 4. Results

Table 10 presents the summary of keywords, frequency and frequency ratios in 1969 and in 1994. In 1969 a total of 54 research papers was published. Utilizing the coding framework (see Table 3), I categorize the 54 published papers into two groups: environmental logic and industrial logic. Out of 54 papers, 53 papers discussed concepts associated with an industrial logic; and 16 papers incorporated the environmental logic. A total of 15 papers incorporated both logics (= 53 + 16 - 54). In addition to the author's categorization, two additional research assistants independently categorized the 54 research papers. Krippendorff's alpha across three coders for environmental logic was .84, and that for industrial logic was .72, exceeding the threshold of 0.68 set forth in Krippendorff (2004) and Neuendorf (2002).

*** Insert Table 10 about here ***

From the 53 papers having incorporated an industrial logic, I calculated the frequency of words. A total of 133,292 words were extracted. Out of the words, I excluded general words (i.e. “a”, “the”, “and”, “but”, “above”, etc.) and technical jargon. I also excluded keywords below the level of the .10% frequency ratio. 13 keywords are identified. Keywords consist of technical performance such as “power”, “speed”, “range” and “efficiency”, economic issues such as “cost” and “economic”, and a market issue “market”.

Similarly, I calculated the frequency of words from the 16 papers having incorporated the environmental logic. A total of 56,681 words were extracted. After excluding general words, technical jargon and words below the level of .10% frequency ratio, I was left with six frequently used keywords including “air”, “people”, “pollution”, “land”, “travel”, and “trip”.

In 1994, a total of 172 papers were published. Out of 172 papers, 153 papers are grouped as an industrial logic; and 63 papers as an environmental logic. Among the papers, 44 have incorporated both logics (= 153 + 63 – 172). Again, two additional research assistants independently coded the papers, based on the coding framework (see Table 3). Krippendorff’s alphas across coders for environmental logic and for industrial logic were .88 and .74 respectively, again exceeding the .68 threshold (Krippendorff 2004; Neuendorf 2002). I used similar exclusion criteria, which left me 13 keywords (i.e., “charging”, “power”, “batteries”, “range”, etc) for the industrial logic and four keywords (i.e., “ emission”, “safety”, “air” and “environment”) for the environmental logic.

Tables 11 and 12 present the co-occurrence similarity matrix using Jaccard’s coefficients in 1969 and in 1994 respectively. A higher score indicates that two words co-occur within the same paragraphs more often, suggesting that the two words are conceptually related. For example, a similarity score between “air” and “pollution” is .24 whereas a similarity score between “air” and “efficiency” is .01. This implies that “air” and “pollution” are semantically closer than “air” and “efficiency”. The similarity measures thus effectively distinguish between environmental and industrial logics because the words “air” and “pollution” represent an environmental logic; whereas the word “efficiency” reflects an industrial logic.

*** Insert Table 11 about here ***

*** Insert Table 12 about here ***

Based on these similarity measures, I conducted a cluster analysis. Figures 6 and 7 present the results of the cluster analysis in 1969 and in 1994, respectively. As shown in Figure 6, the environmental logic consists of six concepts: “air”, “pollution”, “land”, “people”, “trip”, “demand” and “travel” in 1969.

The industrial logic contains ten basic concepts: “battery”, “power”, speed”, “performance”, “range”, “control”, “charging”, time”, “efficiency”, “cost” and “economic”, all of which cover both technical and economic issues. However, the concept “market” was not grouped into either an environmental logic or an industrial logic in 1969.

Figure 7 shows the results of a cluster analysis in 1994. In 1994 the environmental logic now consists of “air”, “emission” and “environment”. The industrial logic has both technical and economic concepts. Compared to the industrial logic in 1969, it appears that new concepts such as “consumer”, “infrastructure” and “utility” were added to an industrial logic in 1994. A new concept “safety” was not grouped into either an environmental logic or an industrial logic. However, the concept “market” is now grouped into both environmental and industrial logics.

*** Insert Figure 6 about here ***

*** Insert Figure 7 about here ***

3. 4. 1. Logic Clarifying

In considering temporal changes in an environmental logic from 1969 to 1994, it appears that the evolution of the environmental logic during this period mostly centers on clarifying the concept of an environmental logic; hence, I identify a *clarifying* mechanism. While discussing air pollution in 1969, most authors who incorporated an initial environmental logic discussed more generic social issues such as “people”, “land”, “travel” and “trip” (see Table 10). In the wake of environmental movements and a series of pollution events in the 1960s, technologists incorporated general social and environmental issues, and discussed them in the technological community. However it appears that technologists did not have a clear understanding of what an environmental logic is and what it means to technology. The results of MDS shown in Figure 8 also indicate that concepts that make up an environmental logic are loosely connected to one another (red cubes). Even a concept “demand” which represents an industrial logic appears to be discussed in terms of an environmental logic. The following are some excerpts from the papers incorporating an environmental logic. Most environmental issues revolve around efficient use of land, general environments, societal issues and air pollution, all of which relate to general and broad environmental and social issues. However, the environmental logic is not tightly linked to technology issues:

> Urban sprawl is eating away at our priceless **land**, **air** and water resources in the outlying areas at a truly alarming rate…. We can stop re enforcing the disequilibrium between **land** development and transportation modes which is built into our present way of doing things…. In achieving a better fit between transportation mode and **land** use, electric vehicles are potentially more ubiquitous than today's transport.
>
> Now we must reevaluate the benefits that accrue if we directly relate the transporting of **people** to their **environment**, to their working conditions, living conditions, recreational facilities, educational facilities, and so on.
>
> This system, linked to the other transportation system components rapid transit for **travel** in metropolitan areas and medium distance high speed corridor trains for intercity **travel** provides city planners with the means for moving more **travelers**, faster, and with ever greater convenience…The high strength pylons occupy minimal ground space and permit the vehicle to **travel** safely above existing highway and pedestrian traffic. …
>
> Nuclear plants although not troublesome on the score of **air pollution**, are a greater **pollution** problem, since for a given capacity the nuclear plant discharges twice as much heat to the cooling water as a fossil fueled plant. …
>
> In recent years there has been a growing belief that as the liquid fuel **demand** of the United States inexorably increases, the domestic petroleum industry will begin to fall behind in its capacity to satisfy that **demand**, despite continued special tax benefits and protection from the world market by an import quota. …

In contrast, as shown in Figure 9, the concepts of an environmental logic in 1994 include emissions, air pollution, and environments. Compared to those in 1969, the concepts in 1994 are less ambiguous and more directly related to environment-specific issues associated with automotive technology. The following are some excerpts from the papers incorporating an environmental logic. These examples well demonstrate that concepts of an environmental logic are now clearer and more tightly related to the specific technology issues in 1994:

> In considering **air pollution** reduction as well as the effective utilization of petroleum resources, we at Honda have always taken an active approach to decreasing **emissions** and increasing fuel efficiency, as our developments of stratified charge combustion (CVCC) and variable valve timing (VTEC) demonstrate. . . .
>
> The public discussion in Europe requires not only vehicles with zero **emissions** at the vehicles operation location, but the global **emissions** have to be at least equal to conventional cars with internal combustion engines (ICE). The most important point in the discussion is the primary energy consumption with its correlation to CO_2 **emissions**. . . .
>
> …The most important first reason of electric vehicle choosers (38%), was the **environmental benefits**. For the second reason of electric vehicle choosers, flexibility of recharging and EVs are the car of the future tied (18%), followed by **environmental benefits** (15%). . . .

These results together imply that actors, faced with a new institutional logic, initially seek to interpret the true meaning of the institutional logic and elaborate the concepts over time. In the EVS, it appears that technologists gradually develop shared understandings of a new institutional logic—environmental logic—through the mechanism of *clarifying*.

*** Insert Figure 8 about here ***

*** Insert Figure 9 about here ***

3. 4. 2. Logic Patching

Faced with multiple and competing logics, actors often incorporate both logics—a *patching* mechanism. Glynn and Lounsbury (2005) found this *patching* mechanism in their study of the Atlanta Symphony Orchestra. An economic crisis forces critics of orchestra performance to incorporate a more commercially-oriented market logic. Because an aesthetic logic had long influenced this profession, critics strategically incorporated some of the elements of a market logic into the aesthetic logic without completely abandoning the traditional aesthetic logic.

Similarly, it appears that this *patching* mechanism has taken place in the electric vehicle profession. Figure 8 shows that concepts between environmental and industrial logics are not connected with each other, suggesting that both logics were conceptually independent in 1969. However, as shown in Figure 9, the concepts of both logics substantially co-occur in the same paragraph in 1994. This indicates that technologists gradually incorporate both logics simultaneously when they discuss technologies. Here are some examples from 1994:

> …Improved **efficiency** to reduce **costs** and **environmental impact** are driving the development of alternative **power** generation technologies. …

> The transit bus demonstrates that a Ballard PEM Fuel Cell Engine can provide the same **performance** as a diesel engine while meeting the requirements for zero **emissions** mandated by the California **Air Resources** Board. …
>
> The **market** for **environmentally**-clean **power** generation is growing as a result of increasing public support for protecting the **environment** and addressing health concerns caused by conventional means of generating **power**. …

3. 4. 3. Logic Expanding

Another mechanism I found is *expanding*. Conceptually and historically, an industrial logic includes technical, economic and market issues. It appears that technical performance, such as technical power, speed and costs were critical issues in an industrial logic in 1969. Further, a market concept was not linked to any of technical and economic concepts. Considering the MDS maps in 1969, it appears that an industrial logic does not embrace a market concept. Here are some excerpts from the papers incorporating an industrial logic in 1969:

> …Because of our interest in going at high **speeds** over long distances on nonstop throughways, we have been giving most of our attention to development of high energy density batteries which will make it possible for electric cars to duplicate the **performance** of the cars we can buy from Detroit today. …
>
> While collection of **power** from the wayside would preferable, it is not at all clear that means can be developed for the quantities of power needed at **speeds** of 200 mph or above. …
>
> The street car has disappeared however there is a significant **market** in metropolitan areas for a transportation system which includes bus service supplementing commuter railroads and rapid transit routes. …This **market** consists largely of the 8 A.M. to 5 P.M. five day a week commuter. …

In contrast, while technical issues are still important, charging infrastructure and battery performance become more important in 1994. The terms "consumer", "infrastructure" and "utility" were newly created as market concepts in 1994. More interestingly, technical, economic and market concepts now become tightly linked to one another in 1994. This result shows that an industrial logic gradually expands into market and economic issues. Some examples are as follows:

> …It confirmed that the **infrastructure costs** to support on-board charging are much lower than those of off-board **charging** and it was concluded that on-board fast **charging** could enable an EV **market**. …
>
> …**Customers** will need to be comfortable about buying EV's, not only from the standpoint of reliability and safety, but also in terms of convenience and **cost** (e.g., the ability to **recharge** an EV's away from home, to easily get EV's repaired, **battery life** and **cost** and the ability to obtain reasonably priced maintenance and repairs.). …
>
> …The provision of 25 kVA **charge** points, therefore, could be more attractive to install than dedicated 7.4 kVA **charge** points, since the higher rates would provide more **utility** for EV owners and the **charge** points would also be able to support those EVs requiring 7.4 kVA **charge** rates. …

3. 4. 4. Logic Reinforcing

A final mechanism of logic framing is *reinforcing*. In Figures 8 and 9, a line across key concepts represents a total number of paragraphs where the two concepts co-occur. A thicker line means that two concepts co-occur more often in the same paragraph. Both MDS maps show that concepts become more tightly connected with one another in both institutional logics over time. That is, three concepts in an environmental logic are more tightly connected with one another, thereby developing its unique identity as an institutional logic in 1996. Moreover, within an industrial logic, technical, economic and market concepts become tightly linked together from 1969 to 1994.

The results together indicate that both institutional logics become less ambiguous and more tightly linked together over time. Actors with different interests mobilize different interpretations of institutional logics and gradually develop shared understandings of institutional logics associated with technologies.

3. 4. 5. Logic Formation and Evolution of Hybrid Drive

Results show that actors incorporating an environmental logic initially struggled with clarifying its meanings. Its concepts were not as clear as those relating to industrial logic in 1969. Moreover, the conceptual elements of environmental logic were loosely connected with one another in 1969. Furthermore, while incorporating some elements of industrial logic, the environmental logic tends to generally isolate itself within its conceptual boundary.

In contrast, actors within the boundary of an industrial logic, while continuing to reinforce its meanings of technical efficiency and economic costs/benefits, actively expand into a new conceptual dimension, by incorporating a market concept. The findings show how an industrial logic becomes a dominant logic over time.

The results together imply that mechanisms of *patching*, *expanding* and *reinforcing* in the industrial logic may support the emergence of hybrid drive. An environmental logic, which supports pure electric drive, is still at the stage of *clarifying*. The findings in this chapter are consistent with, and complement, those in Chapter 2.

3. 5. Discussion

In this chapter I have sought to understand how institutional logics evolve over time and how different formation of institutional logics shape the emergence and decline of new technologies. The prevailing literature on institutional logics tends to still revolve around how institutional logics shape actors' cognition and behaviors. In this study, assuming that institutional logics are endogenous, I focus on how actors can collectively shape institutional logics by mobilizing different interpretations of institutional logics. I analyze research proceedings published by EVS. From the keyword-based, computer-aided text analysis, I found four mechanisms of framing institutional logics—*clarifying*, *patching*, *expanding* and *reinforcing*. Moreover, the results imply that the different evolution of environmental and industrial logics is closely related to the emergence and decline of electric and hybrid drives, which enriches the findings in Chapter 2.

This study has several theoretical and practical implications. First, this study sheds light on theoretical debates on institutional change. A fundamental question that has been debated is how embedded actors whose activities tend to be constrained by broader institutional forces can promote institutional change. Although previous studies on institutional change have proclaimed that external shocks, internal economic crisis, institutional contradictions and misaligned interests of actors serve as sources of institutional change (e.g., Barley and Tolbert 1997; Oliver 1992; Seo and Creed 2002; Tolbert and Zucker 1983), we still know relatively little about how actors respond to competing institutional logics or institutional contradictions, and how different formations of institutional logics systematically influence the process of institutional change.

While recent institutional research has underscored the role of collective actions in institutional change, much of it is limited to theoretical discussion (e.g., Fligstein and McAdam 2011; Hargrave and Van de Ven 2006; Reay and Hinings 2009). In this study I have attempted to address this issue, suggesting that actors collectively and purposefully construct institutional logics by mobilizing their meanings; and that this social process systematically influences the differential evolution of new technologies. That is, institutional logics can be enablers and disablers of institutional change, depending on the process of logic construction by actors.

In particular, in the high-technology industry where the technology life cycle is much shorter, almost every day, social actors encounter new technologies and need to interpret the meanings of new technologies from their own institutional logics. Even within the technology field, scientists and engineers discuss new concepts and technologies during the experimental and developmental stage of new technologies. Technological consensus results from logic contestation. It may be almost impossible to assume that an institutional logic is stable and enduring, at least in the context of technological evolution. A certain institutional logic would help actors understand the usefulness of technology but at the same time preclude the actors from understanding other technologies that may have different institutional logics. It is therefore important to understand the temporal variations of institutional logics. The results in this study will help in better understanding the institutional process of collective actions, which serves as a primary source of institutional change.

Second, this study attempts to bridge structural and agency-based perspectives, in that it explores interactive processes between actors and institutional logics. Based on the critique of technological determinism, scholars highlight human agents' skills and capabilities of disrupting prevailing meaning systems, values, and norms within the institutional field (e.g., Barley and Tolbert 1997; Orlikowski 1992; Purdy and Gray 2009). Although current agency-based studies on technology have contributed to the development of a structurational model of technology, most studies tend to treat technology as a *given*. With this assumption, they then explore social processes through which social actors generate different meanings of new technology and subsequently develop different social structure, order, and roles (i.e., Barley 1987).

Less is known regarding the social and cultural processes influencing the origin or development of new technology. In this study I empirically demonstrate how institutional logics mediate between actors and the emergence of technologies. Institutional logics in the technology context are manifestations of social actors' interpretations of practices associated with technology. In other words, they are social and cultural outcomes resulting from actors' interpretations of new technology. However, established institutional logics at the same time can constrain actors' interpretations. The social mechanisms identified in this study will therefore help in better understanding the reciprocity between actors and institutional logics, particularly in the context of technological evolution.

The findings propose four potential mechanisms of framing institutional logics, such that social actors collectively develop institutional logics and share them within a community (*clarifying*); that the discrepancy among competing logics create social conflicts and lead to the hybridization of the competing logics (*patching*); that an institutional logic expands into a new conceptual dimension, thereby embracing new actors and technologies (*expanding*); and that the established institutional logics guide social actors' cognitive thought-processing (*reinforcing*).

Third, this study attempts to open up the "black box" of endogenous social and cultural processes of technological evolution that have been relatively overlooked in current technology, entrepreneurship and institutional studies. Although early research on the history of economic development has long argued that research and development in universities, scientific laboratories, and industries is one of the major sources of new knowledge, and has emphasized that it is thus necessary to explore the endogenous process of technological development (e.g., Rosenberg 1982; 2000; Tripsas 1997), we still know relatively little about the social and cultural process influencing the origin, development, and consequences of scientific knowledge (Tushman and Rosenkopf 1992).

In particular, it is relatively understudied how social actors collectively interpret new technology or knowledge, and how the institutions or actors' collective mindsets of technology restrict the actors' interpretations of the technology, all of which are important for understanding the endogenous social and cultural processes of technology development. The identification of social mechanisms shaping the emergence and decline of new technologies thus helps us to better understand the social aspects of technological evolution and partly addresses why a certain technology, despite its technological superiority, is not accepted in the technology field and soon disappears in the society.

In addition to the theoretical contributions, identification of four different mechanisms of the evolution of institutional logics provides some strategic implications for entrepreneurs. To be successful entrepreneurs, technology inventors should develop appropriate strategies of communicating with relevant social actors (Hallen and Eisenhardt 2011; Hargadon and Douglas 2001; Fligstein and McAdam 2011). The results show that entrepreneurs or managers should pay more attention to managing actors' institutional logics. Conflicts in institutional logics take place across technological and sociocultural fields. Thus, the alignment of institutional logics across all relevant social actors—such as scientists, engineers, industry professionals, policymakers and technology users—is crucial for a successful launching of a new technology.

When introducing new technology or entering new markets, entrepreneurs may have to choose an appropriate strategy of delivering relevant logics, associated with new technology, products and services, or shaping the existing logics of social actors. Four mechanisms discussed in this study can serve as basic guidelines for the entry strategies of entrepreneurs. Thus, identification of evolutionary mechanisms of institutional logics helps entrepreneurs develop appropriate strategies for the management of the institutional logics.

In this study I have attempted to understand the linkages among actors, institutional logics and technologies. I have found four framing mechanisms of institutional logics, which will help in better understanding the complex social dynamics in the technological evolution.

Figure 1. Embedded Actor, Institutional Logic and Technology

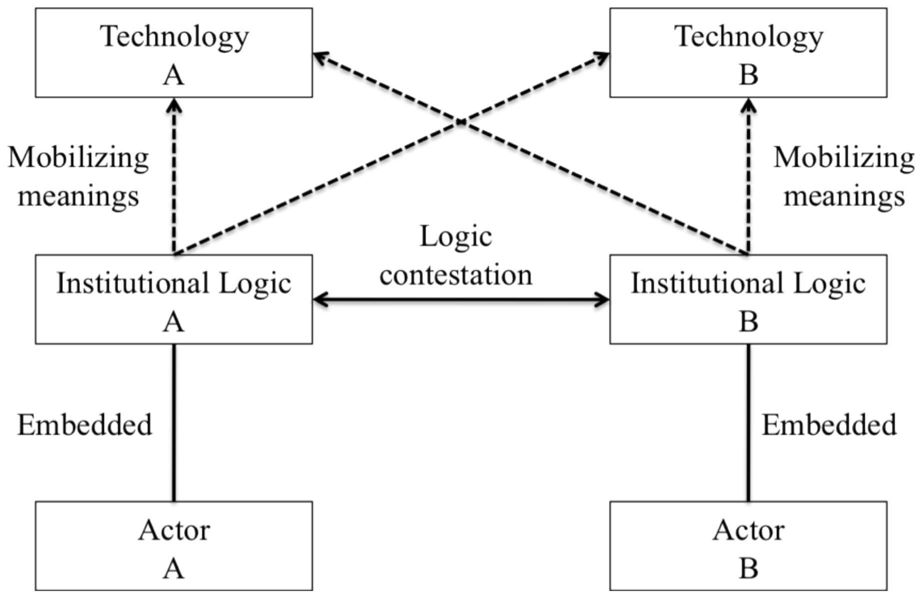


Figure 2. Development of New Technology

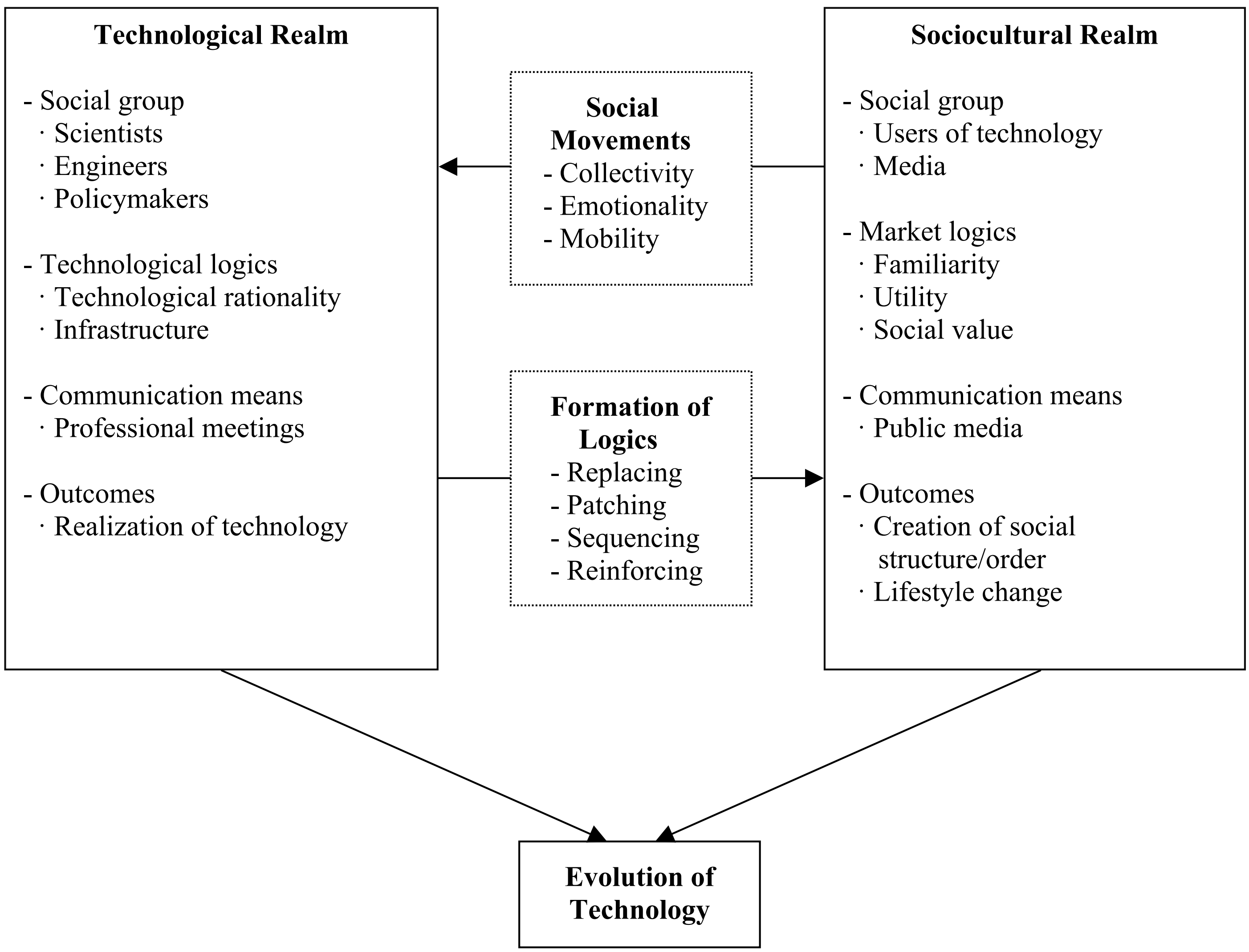


Figure 3. Formation of Institutional Logics and Technology Development

Technological Support of a New Logic		Weak	Strong
	Strong	- Formation of institutional logics : *Sequencing* - Technology development : *Evolutionary* Ex) ICE vs. HV vs. EV	- Formation of institutional logics : *Replacing* - Technology development : *Disruptive* Ex) Horse vs. ICE
	Weak	- Formation of institutional logics : *Reinforcing* - Technology development : *Persistence* Ex) Fossil fuel-based energy system	- Formation of institutional logics : *Patching* - Technology development : *Hybridization* Ex) Vaccine

Sociocultural Support of a New Logic

Table 1. Industrial Logic vs. Environmental Logic

	Institutional logics	
	Industrial logic	Environmental logic
Actors	- Businessmen - Workers	- Conservationists - Environmentalists
Political orientation/norm	- Conservatism - Market control	- Liberalism - Social/legal control
Policy orientation/norm	- Economic development - Efficient use of resources/environments	- Preservation of environments
Value	- Economic growth - Technological innovation - Social welfare	- Health - Quality of life - Humanity
Beliefs	- Economic growth provides jobs, opportunities, and wealth.	- Economic growth destroys our environments, which eventually devastates human life.
Social movement organizations	- American Iron and Steel Institute - Automobile Manufacturers Association - American Petroleum Institute - National Mining Association	- Environment Protection Agency - Greenpeace - Sierra club
Relevant issues in proceedings	- Techno-economic efficiency - Infrastructure - Commercialization - Marketing strategy - Standardization	- Environment - Pollution (air, noise) - Ecology

Figure 4. Contestation between Environmental Logic and Industrial Logic

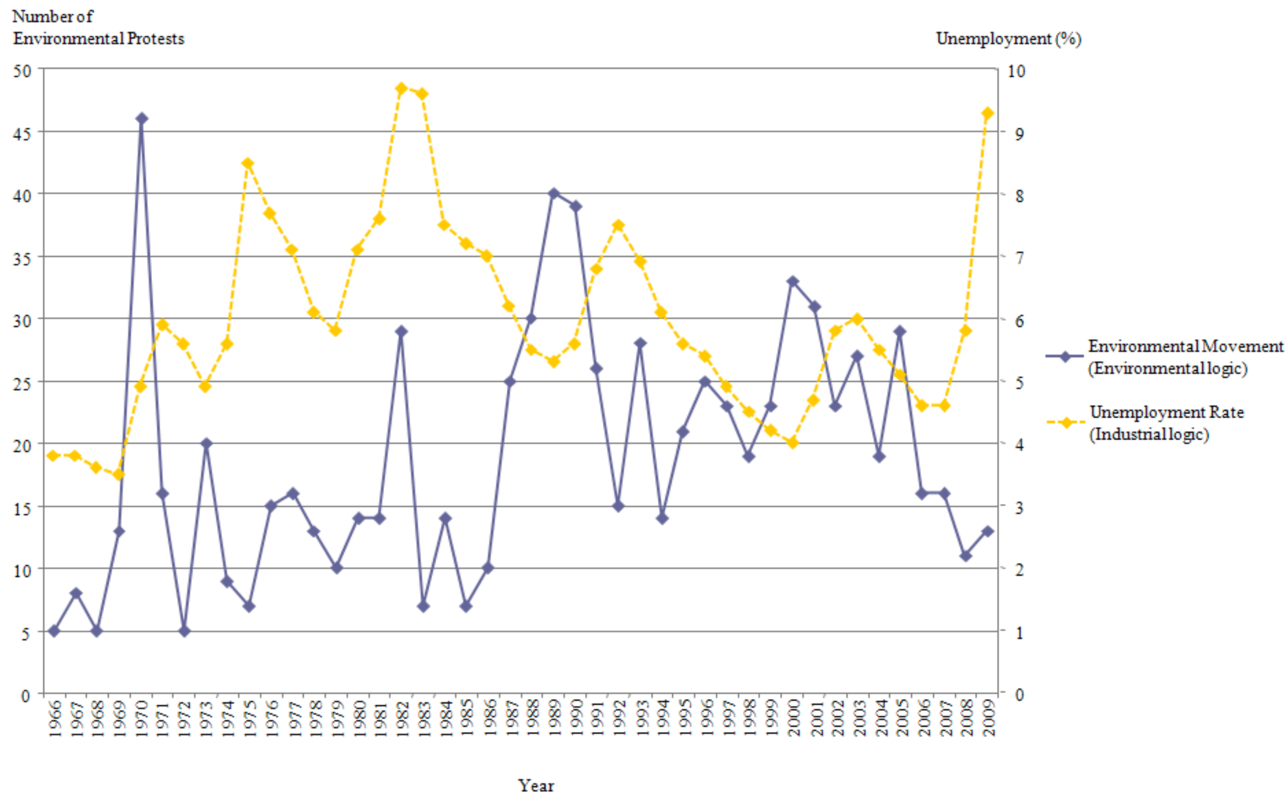


Table 2. Proceedings of International *Electric Vehicle Symposium*

EVS_id	Year	Volume	Data type	Pages	Publishers/Organizers	City	State	Country
1	1969		Book	558	EVC[†]	Phoenix	AZ	US
2	1971		Book	789	EVC	Atlantic City	NJ	US
3	1974	1, 2	Book	1,393	EVC	Washington	DC	US
4	1976	1, 2	Book	1,894	EVC	Dusseldorf		Germany
5	1978		Book	691	EVC	Philadelphia	PA	US
6	1981		Book	601	EVC	Baltimore	MD	US
7	1984		Book	456	AVERE[††]	Versailles		France
8	1986		Book	551	EEI[†††], EPRI[*], EVDC[**]	Washington	DC	US
9	1988		Book	982	EVA[***] Canada	Toronto	Ontario	Canada
10	1990		Book	1,125	WEVA[§], EVAAP[§§]	Hong Kong		China
11	1992	1, 2, 3	Book	2,057	WEVA, AVERE Italy	Florence		Italy
12	1994	1, 2	Book	1,695	WEVA, EVAA[§§§]	Anaheim	CA	US
13	1996	1, 2	Book	1,741	WEVA, EVAAP	Osaka		Japan
14	1997		CD	1,917	WEVA, EVAA	Orlando	FL	US
15	1998		CD	2,003	WEVA, AVERE	Brussels		Belgium
16	1999		CD	1,663	WEVA, EVAAP	Beijing		China
17	2000		CD	2,034	WEVA, EVAA	Montreal	Quebec	Canada
18	2001		CD	2,738	WEVA, AVERE	Berlin		Germany
19	2002		CD	2,156	WEVA, EVAAP	Busan		Korea
20	2003		CD	2,325	WEVA, EDTA[§§§§]	Long Beach	CA	US
21	2005		CD	2,799	WEVA, AVERE	Monaco		Monaco
22	2006		CD	2,401	WEVA, EVAAP	Yokohama		Japan
23	2007		CD	2,534	WEVA, EDTA	Anaheim	CA	US
24	2009		CD	2,900	WEVA, AVERE	Stavanger		Norway

[†]: Electric Vehicle Council; [††]: European Electric Road Vehicle Association; [†††]: Edison Electric Institute; [*]: Electric Power Research Institute; [**]: Electric Vehicle Development Corporation; [***]: Electric Vehicle Association; [§]: World Electric Vehicle Association; [§§]: Electric Vehicle Association of Asia Pacific; [§§§]: Electric Vehicle Association of the Americas; [§§§§]: Electric Drive Transportation Association

Table 3. Keywords of Environmental vs. Industrial Logic

Environmental Logic		Industrial Logic	
"air pollution"	"low emission"	"auxiliary performance"	"infrastructure - technical"
"air quality"	"low pollution"	"battery application"	"infrastructure - legal"
"battery safety"	"motor noise"	"battery efficiency"	"lifecycle cost"
"clean"	"noise emission"	"battery performance"	"market"
"climate change"	"pollutant"	"battery power"	"market analysis"
"CO_2 emission"	"pollution free"	"battery price"	"market strategy"
"ecology"	"pollution reduction"	"battery system performance"	"market supply"
"emission reduction"	"pollution"	"charging infrastructure"	"market trend"
"emission regulation"	"quality of life"	"commercialization"	"marketability"
"emission standard"	"renewable"	"cost of infrastructure"	"marketing"
"emission"	"safety emission"	"cost reduction"	"mass production"
"energy consumption"*	"safety"	"demonstration"	"modeling"
"energy saving"*	"social benefit"	"design"	"optimal design"
"environment"	"social value"	"design optimization"	"optimization"
"environmental benefit"	"sustainability"	"driving range"	"patent policy"
"environment friendly"	"sustainable"	"economic analysis"	"performance"
"environmental impact"	"zero emission"	"economic benefit"	"performance - power"
"environmental issue"		"economic development"	"performance - speed"
"environmental pollution"		"economic efficiency"	"performance test"
"environmental problem"		"economic feasibility"	"power"
"environmental protection"		"economic impact"	"promotion"
"environmental quality"		"economic issue"	"public policy"
"environmental requirement"		"economic performance"	"purchasing price"
"environmental standard"		"economic viability"	"regulation"
"fuel consumption"		"economics"	"regulatory effort"
"fuel economy"		"economy"	"regulatory issue"
"fuel efficiency"		"educational infrastructure"	"simulation"
"fuel saving"		"efficiency"	"standardization"
"gas emission"		"efficiency cost reduction"	"system performance"
"global environment"		"energy efficiency"**	"technical analysis"
"global warming"		"energy storage"	"technical concern"
"greenhouse emission"		"energy supply"***	"technical efficiency"
"greenhouse gas emission"		"engine power"	"technical feasibility"
"greenhouse gas reduction"		"experiment"	"technical performance"
"greenhouse gas"		"infrastructure"	"techno-economic issue"
"health hazard"		"infrastructure-economic"	"techno-economic assessment"

* Keywords "energy consumption" and "energy saving" represent gasoline consumption that is directly related to CO_2 emissions and the protection of the natural environment.
** A keyword "energy efficiency" represents energy losses of electric systems and devices, efficiency of energy conversion, and maximum output of electric systems.
*** A keyword "energy supply" represents the electricity supply for the use of electric vehicles.

Table 4. Definitions of Variables

Variable		Definition
Dependent variables	Environmental Logic $_{(it)}$	1 if a paper's topic is related to environment, pollution and ecology for author *i* at time *t*; 0 otherwise
	Industrial Logic $_{(it)}$	1 if a paper's topic is related to technical and economic efficiency, infrastructure, marketing strategy, standardization and commercialization for author *i* at time *t*; 0 otherwise
	Electric Drive $_{(it)}$	1 if a paper's topic is related to pure electric drive for author *i* at time *t*; 0 otherwise
	Hybrid Drive $_{(it)}$	1 if a paper's topic is related to hybrid drive for author *i* at time *t*; 0 otherwise
Key independent variables	Environmental Protest $_{(t-2)}$	Total number of environmental protest events covered by *New York Times* at time *t-2*
	US Unemployment $_{(t-2)}$	Average unemployment rate in U.S. at time *t-2*
	Cohesion Networks Environmental Logic $_{(t-2)}$	Density of co-authorship networks associated with an environmental logic at time *t-2*
	Cohesion Networks Industrial Logic $_{(t-2)}$	Density of co-authorship networks associated with an industrial logic at time *t-2*
Control variables	Δ Environmental Logic $_{(t-2)}$	[Total number of authors associated with an environmental logic $_{(t-2)}$ – Total number of authors associated with an environmental logic $_{(t-3)}$] / Total number of authors associated with an environmental logic $_{(t-3)}$
	Δ Industrial Logic $_{(t-2)}$	[Total number of authors associated with an industrial logic $_{(t-2)}$ – Number of authors associated with an industrial logic $_{(t-3)}$] / Number of authors associated with an industrial logic $_{(t-3)}$
	Country-fixed effects $_{(it)}$	(Dummies) 1 if the origin of an author *i*'s affiliation is U.S., Canada, Germany, France, Italy, UK, Korea, Japan, or China; 0 otherwise
	Institution-fixed effects $_{(it)}$	(Dummies) 1 if an author *i*'s affiliation is universities (*University*), governments (*Government*), government-sponsored research institution (*G-sponsored research*), independent private research institutions (*Research*), or companies (*Industry*); 0 otherwise
	Motor type-fixed effects $_{(it)}$	(Dummies) 1 if an author *i* discusses DC motor, AC motor, induction motor, permanent magnet motor, or switched reluctance motor; 0 otherwise
	Energy source-fixed effects $_{(it)}$	(Dummies) 1 if an author *i* discusses lead acid batteries, nickel-based batteries, lithium-based batteries, fuel cells, zinc air-based batteries, or capacitors/flywheels; 0 otherwise
	Δ US CO_2 Emission $_{(t-2)}$	[Total emission of carbon dioxide in U.S. $_{(t-2)}$ - Total emission of carbon dioxide in U.S. $_{(t-3)}$]/ Total emission of carbon dioxide in U.S. $_{(t-3)}$
	Δ US Car Price $_{(t-2)}$	[Average price of domestic internal combustion engine passenger cars in U.S. $_{(t-2)}$ - Average price of domestic internal combustion engine passenger cars in U.S. $_{(t-3)}$] / Average price of domestic internal combustion engine passenger cars in U.S. $_{(t-3)}$
	Δ US Oil Price $_{(t-2)}$	[Average oil price per barrel in U.S. $_{(t-2)}$ - Average oil price per barrel in U.S. $_{(t-3)}$] / Average oil price per barrel in U.S. $_{(t-3)}$

Table 5. Descriptive Statistics and Correlations (N = 11421)

Variable	Mean	SD	Min	Max	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Environmental Logic $_{(it)}$	0.37	0.48	0.00	1.00	1.00											
(2) Industrial Logic $_{(it)}$	0.94	0.24	0.00	1.00	-0.32	1.00										
(3) Hybrid Drive $_{(it)}$	0.38	0.49	0.00	1.00	0.20	0.02	1.00									
(4) Electric Drive $_{(it)}$	0.71	0.46	0.00	1.00	-0.20	-0.01	-0.81	1.00								
(5) Environmental Protest $_{(t-2)}$	22.94	7.18	9.00	39.00	0.05	-0.03	0.08	-0.09	1.00							
(6) US Unemployment $_{(t-2)}$ (%)	5.34	1.01	4.00	9.70	-0.09	0.03	-0.21	0.17	-0.27	1.00						
(7) Cohesion Networks Environmental Logic $_{(t-2)}$	19.85	15.18	10.20	88.90	-0.13	0.01	-0.22	0.19	0.05	0.48	1.00					
(8) Cohesion Networks Industrial Logic $_{(t-2)}$	7.68	3.06	5.20	19.90	-0.11	0.00	-0.20	0.17	0.03	0.50	0.89	1.00				
(9) Δ Environmental Logic $_{(t-2)}$	32.35	67.51	-85.42	230.00	-0.04	-0.02	-0.17	0.14	0.19	0.31	0.30	0.44	1.00			
(10) Δ Industrial Logic $_{(t-2)}$	15.92	35.97	-24.42	109.28	-0.03	0.00	-0.12	0.10	-0.15	0.25	0.01	-0.01	0.56	1.00		
(11) US $_{(it)}$	0.20	0.40	0.00	1.00	0.00	0.02	0.04	-0.03	-0.07	0.06	0.09	0.08	-0.04	0.03	1.00	
(12) Canada $_{(it)}$	0.03	0.16	0.00	1.00	0.01	-0.03	-0.02	0.03	-0.02	0.04	0.09	0.07	0.06	0.01	-0.08	1.00
(13) Germany $_{(it)}$	0.07	0.26	0.00	1.00	-0.03	0.01	0.01	0.01	0.00	0.03	0.02	0.02	0.01	-0.01	-0.14	-0.05
(14) France $_{(it)}$	0.07	0.26	0.00	1.00	-0.04	0.01	-0.03	0.02	-0.01	0.06	0.04	0.02	0.02	0.02	-0.14	-0.05
(15) Italy $_{(it)}$	0.04	0.21	0.00	1.00	0.02	0.00	0.03	0.00	0.08	0.04	0.09	0.10	0.08	0.01	-0.11	-0.04
(16) UK $_{(it)}$	0.03	0.16	0.00	1.00	-0.02	0.02	0.02	-0.03	-0.02	0.04	0.04	0.05	0.01	-0.01	-0.08	-0.03
(17) Korea $_{(it)}$	0.05	0.21	0.00	1.00	0.00	0.01	0.10	-0.13	0.07	-0.13	-0.07	-0.05	-0.05	-0.06	-0.11	-0.04
(18) Japan $_{(it)}$	0.23	0.42	0.00	1.00	0.00	0.01	-0.08	0.05	-0.04	0.01	-0.07	-0.08	0.10	0.11	-0.28	-0.09
(19) China $_{(it)}$	0.06	0.24	0.00	1.00	-0.03	0.04	-0.03	0.02	0.06	-0.07	-0.07	-0.08	-0.09	-0.10	-0.13	-0.04
(20) University $_{(it)}$	0.34	0.47	0.00	1.00	-0.03	-0.01	-0.04	0.02	0.08	-0.13	-0.09	-0.08	-0.11	-0.12	-0.19	-0.03
(21) Government $_{(it)}$	0.04	0.20	0.00	1.00	0.04	-0.07	-0.04	0.08	-0.04	0.05	0.07	0.05	0.04	0.03	0.10	0.07
(22) G-sponsored Research $_{(it)}$	0.09	0.29	0.00	1.00	0.03	-0.03	0.08	-0.06	-0.01	0.02	-0.02	0.00	-0.04	-0.02	0.13	-0.04
(23) Private Research $_{(it)}$	0.07	0.25	0.00	1.00	0.07	-0.03	0.02	-0.01	0.01	-0.07	-0.04	-0.05	-0.04	-0.02	-0.01	0.01
(24) Industry $_{(it)}$	0.44	0.50	0.00	1.00	-0.04	0.08	0.00	-0.01	-0.07	0.13	0.09	0.07	0.13	0.14	0.09	0.02
(25) Δ US Oil Price $_{(t-2)}$	0.15	0.28	-0.48	0.77	0.05	-0.02	0.12	-0.14	0.34	-0.32	-0.20	-0.03	-0.22	-0.28	-0.06	-0.07
(26) Δ US Car Price $_{(t-2)}$	0.03	0.03	0.00	0.11	-0.12	0.02	-0.22	0.19	-0.23	0.59	0.50	0.48	0.50	0.55	0.11	0.04
(27) Δ US CO_2 Emission $_{(t-2)}$	0.01	0.02	-0.05	0.06	0.00	-0.01	-0.01	-0.01	-0.22	-0.09	-0.13	-0.17	-0.35	0.04	0.02	-0.02
(28) AC Motor $_{(it)}$	0.02	0.15	0.00	1.00	-0.02	0.03	-0.01	0.00	0.01	0.03	0.04	0.02	0.03	0.04	-0.01	-0.01
(29) DC Motor $_{(it)}$	0.04	0.21	0.00	1.00	-0.04	0.05	-0.06	0.05	0.02	0.02	0.02	0.00	-0.01	-0.04	-0.06	-0.01
(30) Induction Motor $_{(it)}$	0.03	0.17	0.00	1.00	-0.04	0.04	-0.01	0.01	0.01	0.04	0.02	0.02	0.03	0.03	-0.02	-0.02
(31) Permanent Magnet Motor $_{(it)}$	0.05	0.22	0.00	1.00	-0.10	0.03	-0.02	0.00	-0.01	-0.01	0.00	-0.02	0.00	0.02	-0.07	-0.02
(32) Switched Reluctance Motor $_{(it)}$	0.01	0.11	0.00	1.00	-0.05	0.03	-0.03	0.04	0.03	-0.03	-0.02	-0.03	-0.02	0.00	-0.04	-0.02
(33) Capacitor Flywheel $_{(it)}$	0.07	0.25	0.00	1.00	-0.04	0.04	0.08	-0.10	0.03	-0.09	-0.08	-0.09	-0.06	-0.03	-0.04	-0.03
(34) Fuel Cell Battery $_{(it)}$	0.13	0.34	0.00	1.00	0.07	0.03	-0.01	0.05	0.10	-0.10	-0.12	-0.11	-0.10	-0.09	0.01	0.01
(35) Lead Acid Battery $_{(it)}$	0.08	0.27	0.00	1.00	-0.13	0.06	-0.10	0.08	-0.06	0.09	0.07	0.06	0.07	0.09	0.03	0.01
(36) Lithium-based Battery $_{(it)}$	0.12	0.32	0.00	1.00	-0.02	0.05	0.08	-0.05	0.00	-0.10	-0.11	-0.11	-0.08	-0.05	-0.02	0.06
(37) Nickel-based Battery $_{(it)}$	0.09	0.29	0.00	1.00	-0.11	0.04	0.01	-0.02	0.01	0.04	0.03	0.02	0.03	0.02	0.05	0.00
(38) ZincAir-based Battery $_{(it)}$	0.01	0.11	0.00	1.00	-0.04	0.03	-0.06	0.06	0.01	0.04	0.10	0.08	0.01	0.00	0.02	0.10

Continued

Table 5. *(continued)*

(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)
1.00																								
-0.08	1.00																							
-0.06	-0.06	1.00																						
-0.05	-0.05	-0.04	1.00																					
-0.06	-0.06	-0.05	-0.04	1.00																				
-0.15	-0.15	-0.12	-0.09	-0.12	1.00																			
-0.07	-0.07	-0.06	-0.04	-0.06	-0.14	1.00																		
0.04	-0.05	0.04	0.06	0.05	-0.19	0.24	1.00																	
-0.06	-0.01	-0.04	0.00	-0.01	-0.04	-0.03	-0.15	1.00																
-0.07	0.02	0.07	-0.05	-0.03	0.01	-0.08	-0.23	-0.07	1.00															
-0.02	0.00	-0.05	-0.04	-0.04	-0.07	0.02	-0.19	-0.06	-0.08	1.00														
0.04	0.04	-0.05	-0.01	0.01	0.24	-0.18	-0.64	-0.19	-0.28	-0.24	1.00													
0.04	-0.02	0.01	0.01	0.12	-0.03	0.01	0.08	-0.06	0.03	0.00	-0.08	1.00												
0.00	0.06	0.03	0.03	-0.12	0.02	-0.06	-0.16	0.06	0.01	-0.04	0.16	-0.32	1.00											
-0.05	-0.04	-0.03	-0.01	0.05	0.04	0.00	0.01	0.01	0.02	-0.01	0.00	0.21	-0.06	1.00										
-0.01	-0.01	0.02	0.00	-0.01	0.01	0.04	0.03	-0.03	-0.02	-0.03	0.01	-0.04	0.02	0.00	1.00									
-0.02	0.01	-0.01	0.01	-0.02	0.05	0.00	0.05	-0.02	-0.02	-0.02	-0.02	0.00	0.01	-0.04	0.04	1.00								
0.01	-0.03	0.01	-0.01	0.00	-0.01	0.06	0.04	-0.03	-0.02	-0.01	0.00	0.00	0.03	0.03	0.05	-0.03	1.00							
-0.03	0.00	-0.01	0.01	0.01	0.05	0.05	0.05	-0.04	-0.03	-0.02	0.00	-0.02	0.00	0.04	0.00	0.03	0.02	1.00						
0.14	-0.02	-0.01	0.00	-0.01	-0.06	0.02	0.08	-0.02	-0.02	-0.03	-0.04	0.01	-0.02	0.02	0.00	-0.01	0.09	0.00	1.00					
0.00	-0.01	0.05	0.02	-0.02	-0.01	-0.01	0.05	-0.02	-0.01	-0.06	0.00	0.04	-0.09	0.00	0.02	0.00	-0.01	0.00	-0.01	1.00				
0.02	-0.02	0.04	-0.02	0.07	-0.06	0.03	0.03	-0.01	0.04	-0.02	-0.04	0.08	-0.17	-0.04	0.02	-0.03	-0.01	-0.09	0.01	0.05	1.00			
0.03	-0.02	0.05	0.01	-0.05	0.01	-0.02	-0.02	0.00	0.00	-0.03	0.04	-0.05	0.12	0.05	0.00	-0.01	-0.02	-0.04	-0.03	-0.01	-0.08	1.00		
-0.02	0.04	-0.06	-0.05	0.01	0.08	-0.05	-0.12	-0.01	0.06	0.07	0.05	0.04	-0.10	0.00	-0.05	0.00	-0.04	-0.03	-0.01	-0.04	-0.10	-0.03	1.00	
0.00	0.03	-0.05	-0.04	-0.01	0.07	-0.02	-0.10	0.02	-0.02	-0.02	0.12	-0.05	0.05	0.01	0.01	-0.01	-0.05	-0.06	-0.03	-0.05	-0.07	0.12	0.02	1.00
0.02	-0.02	-0.01	0.01	-0.02	-0.04	-0.03	0.00	0.02	-0.03	-0.03	0.02	-0.06	0.04	0.01	-0.01	-0.02	-0.01	-0.02	-0.01	0.03	-0.03	0.03	-0.03	0.02

Table 6. Probit Regressions of Institutional Logics

Variable	DV = Industrial Logic $_{(it)}$				DV = Environmental Logic $_{(it)}$			
	Model 1		Model 2		Model 3		Model 4	
	β	ME	β	ME	β	ME	β	ME
Country effects								
US $_{(it)}$	0.210***	0.021***	0.212***	0.021***	-0.077**	-0.029**	-0.079**	-0.029**
	(3.53)	(3.92)	(3.56)	(3.96)	(-1.93)	(-1.95)	(-1.99)	(-2.01)
Canada $_{(it)}$	-0.155*	-0.019*	-0.153*	-0.019*	0.028	0.010	0.030	0.011
	(-1.49)	(-1.34)	(-1.47)	(-1.32)	(0.35)	(0.34)	(0.37)	(0.37)
Germany $_{(it)}$	0.182**	0.018***	0.176**	0.017***	-0.200***	-0.072***	-0.195***	-0.071***
	(2.16)	(2.48)	(2.10)	(2.39)	(-3.73)	(-3.89)	(-3.64)	(-3.78)
France $_{(it)}$	0.193***	0.019***	0.200***	0.019***	-0.268***	-0.096***	-0.267***	-0.095***
	(2.34)	(2.69)	(2.43)	(2.81)	(-4.94)	(-5.25)	(-4.91)	(-5.21)
Italy $_{(it)}$	0.115	0.012*	0.136*	0.014*	0.083*	0.032*	0.081	0.031
	(1.19)	(1.30)	(1.42)	(1.59)	(1.32)	(1.30)	(1.27)	(1.26)
UK $_{(it)}$	0.412***	0.033***	0.401***	0.033***	-0.194***	-0.070***	-0.188***	-0.068***
	(2.81)	(4.10)	(2.74)	(3.95)	(-2.43)	(-2.54)	(-2.34)	(-2.44)
Korea $_{(it)}$	0.254***	0.023***	0.272***	0.025***	-0.150***	-0.055***	-0.163***	-0.059***
	(2.57)	(3.14)	(2.74)	(3.41)	(-2.42)	(-2.50)	(-2.62)	(-2.71)
Japan $_{(it)}$	0.089*	0.010*	0.095*	0.010**	-0.082**	-0.031**	-0.084**	-0.031**
	(1.54)	(1.60)	(1.64)	(1.71)	(-2.11)	(-2.13)	(-2.16)	(-2.17)
China $_{(it)}$	0.649***	0.046***	0.668***	0.047***	-0.235***	-0.085***	-0.242***	-0.087***
	(5.81)	(10.23)	(5.98)	(10.71)	(-4.20)	(-4.42)	(-4.32)	(-4.56)
Institution effects								
University $_{(it)}$	0.308***	0.032***	0.310***	0.032***	-0.099	-0.037	-0.106	-0.039
	(2.63)	(2.81)	(2.65)	(2.83)	(-1.06)	(-1.07)	(-1.14)	(-1.15)
Government $_{(it)}$	-0.141	-0.017	-0.147	-0.018	0.257***	0.100**	0.256***	0.099**
	(-1.05)	(-0.95)	(-1.09)	(-0.99)	(2.37)	(2.32)	(2.36)	(2.31)
G-sponsored Research $_{(it)}$	0.178*	0.018*	0.171*	0.017*	0.103	0.039	0.103	0.039
	(1.39)	(1.58)	(1.34)	(1.50)	(1.02)	(1.01)	(1.03)	(1.01)
Private Research $_{(it)}$	0.197*	0.019**	0.208*	0.020**	0.293***	0.114***	0.281***	0.109***
	(1.52)	(1.76)	(1.61)	(1.88)	(2.89)	(2.83)	(2.78)	(2.72)
Industry $_{(it)}$	0.554***	0.060***	0.549***	0.059***	-0.036	-0.014	-0.038	-0.014
	(4.61)	(4.68)	(4.57)	(4.64)	(-0.39)	(-0.39)	(-0.40)	(-0.40)
Substitution effects								
Δ US Oil Price $_{(t-2)}$	-0.095	-0.011	0.016	0.002	0.072*	0.027*	0.024	0.009
	(-1.25)	(-1.25)	(0.21)	(0.21)	(1.51)	(1.51)	(0.48)	(0.48)
Δ US Car Price $_{(t-2)}$	0.884	0.098	-0.191	-0.021	-6.198***	-2.327***	-5.259***	-1.974***
	(1.23)	(1.23)	(-0.21)	(-0.21)	(-12.17)	(-12.17)	(-8.82)	(-8.82)
Pollution effects								
Δ US CO_2 Emission $_{(t-2)}$	-0.459	-0.051	-1.535*	-0.170*	-0.832	-0.312	-0.505	-0.189
	(-0.42)	(-0.42)	(-1.39)	(-1.39)	(-1.11)	(-1.11)	(-0.63)	(-0.63)
Main effects								
Environmental Protest $_{(t-2)}$			-0.008***	-0.001***			0.002	0.001
			(-2.62)	(-2.63)			(1.25)	(1.25)
US Unemployment $_{(t-2)}$ (%)			0.048**	0.005**			-0.046***	-0.017***
			(1.94)	(1.95)			(-2.94)	(-2.94)
Constant	1.064***		1.010***		-0.063		0.107	
	(9.16)		(5.43)		(-0.68)		(0.80)	
N	11421		11421		11421		11421	
Log Likelihood	-2527.430		-2521.518		-7336.849		-7331.079	
-2ΔL			11.824***				11.540***	

*: p < .10; **: p < .05; ***: p < .01 (one-tailed test)
t-statistics in parentheses; robust standard errors used

Table 7. Probit Regressions of Electric and Hybrid Drives

Variable	DV = Electric Drive $_{(it)}$				DV = Hybrid Drive $_{(it)}$			
	Model 5		Model 6		Model 7		Model 8	
	β	ME	β	ME	β	ME	β	ME
Country effects								
US $_{(it)}$	-0.164***	-0.056***	-0.192***	-0.064***	0.107***	0.041***	0.135***	0.051***
	(-3.84)	(-3.74)	(-4.40)	(-4.26)	(2.60)	(2.58)	(3.24)	(3.20)
Canada $_{(it)}$	-0.048	-0.016	-0.098	-0.032	-0.010	-0.004	0.046	0.017
	(-0.52)	(-0.51)	(-1.02)	(-0.99)	(-0.11)	(-0.11)	(0.54)	(0.54)
Germany $_{(it)}$	-0.046	-0.015	-0.087*	-0.029*	0.086*	0.033*	0.114**	0.043**
	(-0.80)	(-0.79)	(-1.51)	(-1.48)	(1.56)	(1.55)	(2.08)	(2.05)
France $_{(it)}$	0.065	0.021	0.024	0.008	-0.160***	-0.059***	-0.142***	-0.052***
	(1.11)	(1.14)	(0.41)	(0.41)	(-2.86)	(-2.95)	(-2.53)	(-2.60)
Italy $_{(it)}$	-0.134**	-0.046**	-0.253***	-0.087***	0.304***	0.118***	0.392***	0.153***
	(-1.92)	(-1.86)	(-3.49)	(-3.30)	(4.60)	(4.51)	(5.82)	(5.71)
UK $_{(it)}$	-0.399***	-0.145***	-0.467***	-0.168***	0.291***	0.113***	0.335***	0.130***
	(-4.79)	(-4.49)	(-5.41)	(-5.01)	(3.54)	(3.47)	(3.99)	(3.90)
Korea $_{(it)}$	-0.644***	-0.240***	-0.616***	-0.226***	0.375***	0.146***	0.363***	0.141***
	(-10.11)	(-9.54)	(-9.62)	(-8.92)	(5.97)	(5.86)	(5.78)	(5.65)
Japan $_{(it)}$	0.108***	0.035***	0.122***	0.038***	-0.228***	-0.084***	-0.248***	-0.090***
	(2.56)	(2.61)	(2.87)	(2.94)	(-5.61)	(-5.78)	(-6.07)	(-6.27)
China $_{(it)}$	0.061	0.020	0.122**	0.038**	-0.174***	-0.063***	-0.224***	-0.080***
	(1.00)	(1.02)	(2.00)	(2.08)	(-2.99)	(-3.10)	(-3.79)	(-3.98)
Institution effects								
University $_{(it)}$	0.159*	0.052**	0.195**	0.061**	0.148*	0.056*	0.130	0.049
	(1.63)	(1.66)	(1.92)	(1.96)	(1.49)	(1.48)	(1.27)	(1.26)
Government $_{(it)}$	0.686***	0.178***	0.685***	0.171***	0.105	0.040	0.115	0.044
	(5.58)	(7.83)	(5.35)	(7.59)	(0.90)	(0.89)	(0.95)	(0.94)
G-sponsored Research $_{(it)}$	-0.233**	-0.081**	-0.181**	-0.061*	0.629***	0.246***	0.595***	0.232***
	(-2.24)	(-2.14)	(-1.67)	(-1.60)	(5.93)	(5.99)	(5.48)	(5.48)
Private Research $_{(it)}$	0.041	0.013	0.073	0.023	0.297***	0.115***	0.283***	0.109***
	(0.39)	(0.39)	(0.67)	(0.68)	(2.76)	(2.70)	(2.57)	(2.51)
Industry $_{(it)}$	-0.039	-0.013	-0.033	-0.011	0.395***	0.149***	0.395***	0.148***
	(-0.40)	(-0.40)	(-0.32)	(-0.32)	(3.93)	(3.94)	(3.82)	(3.84)
Substitution effects								
Δ US Oil Price $_{(t-2)}$	-0.368***	-0.122***	-0.174***	-0.056***	0.164***	0.062***	0.037	0.014
	(-6.71)	(-6.71)	(-2.58)	(-2.57)	(3.16)	(3.16)	(0.59)	(0.59)
Δ US Car Price $_{(t-2)}$	6.118***	2.023***	0.023	0.007	-5.918***	-2.223***	-0.724	-0.270
	(8.12)	(8.13)	(0.03)	(0.03)	(-8.15)	(-8.16)	(-0.89)	(-0.89)
Pollution effects								
Δ US CO_2 Emission $_{(t-2)}$	5.097***	1.685***	1.940*	0.624*	-6.448***	-2.422***	-4.245***	-1.584***
	(5.51)	(5.53)	(1.59)	(1.58)	(-7.23)	(-7.24)	(-4.05)	(-4.03)
Technology effects - motor								
AC Motor $_{(it)}$	-0.118*	-0.040	-0.211**	-0.072**	0.076	0.029	0.163**	0.062**
	(-1.30)	(-1.26)	(-2.21)	(-2.10)	(0.86)	(0.85)	(1.75)	(1.72)
DC Motor $_{(it)}$	0.355***	0.105***	0.332***	0.096***	-0.407***	-0.140***	-0.395***	-0.135***
	(5.03)	(5.78)	(4.58)	(5.24)	(-6.06)	(-6.79)	(-5.79)	(-6.48)
Induction Motor $_{(it)}$	-0.031	-0.010	-0.059	-0.019	0.017	0.006	0.028	0.010
	(-0.39)	(-0.39)	(-0.73)	(-0.72)	(0.23)	(0.23)	(0.37)	(0.37)
Permanent Magnet Motor $_{(it)}$	0.017	0.005	-0.010	-0.003	-0.102**	-0.038**	-0.087*	-0.032*
	(0.28)	(0.28)	(-0.16)	(-0.16)	(-1.77)	(-1.81)	(-1.50)	(-1.53)

(continued)

Table 7 *(continued)*

Switched Reluctance Motor $_{(it)}$	0.782***	0.190***	0.822***	0.188***	-0.587***	-0.190***	-0.606***	-0.193***
	(5.09)	(7.99)	(5.29)	(8.76)	(-4.68)	(-5.80)	(-4.74)	(-5.98)
Technology effects - energy source								
Capacitor Flywheel $_{(it)}$	-0.492***	-0.180***	-0.471***	-0.168***	0.339***	0.132***	0.317***	0.123***
	(-9.93)	(-9.30)	(-9.34)	(-8.65)	(6.88)	(6.75)	(6.42)	(6.27)
Fuel Cell Battery $_{(it)}$	0.468***	0.137***	0.522***	0.145***	-0.309***	-0.111***	-0.352***	-0.124***
	(11.17)	(13.03)	(12.08)	(14.66)	(-7.89)	(-8.39)	(-8.84)	(-9.55)
Lead Acid Battery $_{(it)}$	0.417***	0.121***	0.393***	0.112***	-0.440***	-0.151***	-0.424***	-0.145***
	(7.36)	(8.61)	(6.88)	(7.98)	(-8.24)	(-9.27)	(-7.91)	(-8.88)
Lithium-based Battery $_{(it)}$	-0.039	-0.013	0.009	0.003	0.141***	0.054***	0.104***	0.039***
	(-0.97)	(-0.97)	(0.23)	(0.23)	(3.62)	(3.57)	(2.68)	(2.65)
Nickel-based Battery $_{(it)}$	-0.185***	-0.064***	-0.187***	-0.063***	0.113***	0.043***	0.105***	0.040**
	(-4.03)	(-3.88)	(-4.04)	(-3.88)	(2.51)	(2.48)	(2.34)	(2.31)
ZincAir-based Battery $_{(it)}$	1.162***	0.235***	1.095***	0.219***	-0.811***	-0.242***	-0.723***	-0.220***
	(5.55)	(12.98)	(4.78)	(10.60)	(-5.16)	(-7.43)	(-4.23)	(-5.76)
Institutional logic effects								
Environmental Protest $_{(t-2)}$	-0.012***	-0.004***	-0.027***	-0.009***	0.009***	0.003***	0.020***	0.007***
	(-5.39)	(-5.40)	(-10.10)	(-10.22)	(4.32)	(4.32)	(7.68)	(7.72)
US Unemployment $_{(t-2)}$ (%)	0.079***	0.026***	0.043**	0.014**	-0.151***	-0.057***	-0.101***	-0.038***
	(4.39)	(4.40)	(2.04)	(2.05)	(-8.79)	(-8.81)	(-5.27)	(-5.28)
Δ Environmental Logic $_{(t-2)}$	0.003***	0.001***	0.003***	0.001***	-0.003***	-0.001***	-0.003***	-0.001***
	(10.16)	(10.22)	(8.01)	(8.00)	(-11.27)	(-11.28)	(-8.22)	(-8.22)
Δ Industrial Logic $_{(t-2)}$	-0.003***	-0.001***	0.000	0.000	0.003***	0.001***	0.000	0.000
	(-6.23)	(-6.24)	(-0.64)	(-0.64)	(5.13)	(5.13)	(-0.48)	(-0.48)
Main effects								
Cohesion Networks			0.039***	0.013***			-0.026***	-0.010***
Environmental Logic $_{(t-2)}$			(9.50)	(9.91)			(-8.19)	(-8.28)
Cohesion Networks			-0.072***	-0.023***			0.032***	0.012***
Industrial Logic $_{(t-2)}$			(-4.71)	(-4.77)			(2.42)	(2.42)
Constant	0.151		0.640***		0.317**		-0.064	
	(1.01)		(3.87)		(2.17)		(-0.40)	
N	11421		11421		11421		11421	
Log Likelihood	-6222.816		-6077.323		-6845.017		-6730.696	
-2ΔL			290.986***				228.642***	

*: p < .10; **: p < .05; ***: p < .01 (one-tailed test)
t-statistics in parentheses; robust standard errors used

Table 8. Probit Regressions of Hybrid Drive
(median split by COHESION NETWORKS ENVIRONMENTAL LOGIC $_{(t-2)}$)

Variable†	DV = Hybrid Drive $_{(it)}$			
	High Cohesion Networks Environmental Logic		Low Cohesion Networks Environmental Logic	
	Model 9		Model 10	
	β	ME	β	ME
Country effects				
US $_{(it)}$	0.148***	0.051**	0.112**	0.044**
	(2.37)	(2.32)	(1.92)	(1.91)
Canada $_{(it)}$	-0.473***	-0.135***	0.554***	0.216***
	(-3.52)	(-4.31)	(4.20)	(4.48)
Germany $_{(it)}$	0.050	0.017	0.229***	0.091***
	(0.65)	(0.64)	(2.76)	(2.77)
France $_{(it)}$	-0.229***	-0.072***	-0.006	-0.002
	(-2.83)	(-3.04)	(-0.07)	(-0.07)
Italy $_{(it)}$	0.284***	0.101***	0.809***	0.304***
	(3.22)	(3.06)	(7.00)	(8.18)
UK $_{(it)}$	0.274***	0.098**	0.415***	0.164***
	(2.40)	(2.28)	(3.48)	(3.59)
Korea $_{(it)}$	0.300***	0.108***	0.359***	0.142***
	(3.23)	(3.06)	(4.07)	(4.14)
Japan $_{(it)}$	-0.134**	-0.044***	-0.330***	-0.128***
	(-2.29)	(-2.34)	(-5.50)	(-5.66)
China $_{(it)}$	-0.207**	-0.065**	-0.161**	-0.063**
	(-2.02)	(-2.17)	(-2.17)	(-2.20)
Institution effects				
University $_{(it)}$	-0.156	-0.051	0.400***	0.158***
	(-1.15)	(-1.17)	(2.76)	(2.79)
Government $_{(it)}$	-0.043	-0.014	0.342**	0.136**
	(-0.27)	(-0.28)	(1.98)	(2.01)
G-sponsored Research $_{(it)}$	0.269**	0.096**	0.987***	0.364***
	(1.85)	(1.77)	(6.38)	(7.77)
Private Research $_{(it)}$	-0.006	-0.002	0.552***	0.216***
	(-0.04)	(-0.04)	(3.58)	(3.77)
Industry $_{(it)}$	0.083	0.028	0.803***	0.312***
	(0.60)	(0.60)	(5.48)	(5.78)
Substitution effects				
Δ US Oil Price $_{(t-2)}$	0.962***	0.323***	1.170***	0.464***
	(8.01)	(8.12)	(8.08)	(8.08)
Technology effects - motor				
AC Motor $_{(it)}$	0.317***	0.114***	-0.036	-0.014
	(2.67)	(2.52)	(-0.26)	(-0.26)
DC Motor $_{(it)}$	-0.348***	-0.105***	-0.441***	-0.166***
	(-3.62)	(-4.13)	(-4.79)	(-5.19)
Induction Motor $_{(it)}$	-0.024	-0.008	0.483***	0.190***
	(-0.25)	(-0.25)	(3.88)	(4.07)

(continued)

Table 8 *(continued)*

Permanent Magnet Motor $_{(it)}$	0.195***	0.068***	-0.372***	-0.142***
	(2.54)	(2.44)	(-4.26)	(-4.52)
Switched Reluctance Motor $_{(it)}$	-0.548***	-0.151***	-0.709***	-0.251***
	(-2.85)	(-3.70)	(-4.02)	(-4.92)
Technology effects - energy source				
Capacitor Flywheel $_{(it)}$	0.399***	0.145***	0.182***	0.072***
	(5.62)	(5.29)	(2.59)	(2.59)
Fuel Cell Battery $_{(it)}$	-0.139**	-0.045**	-0.637***	-0.238***
	(-2.22)	(-2.30)	(-12.11)	(-13.38)
Lead Acid Battery $_{(it)}$	-0.341***	-0.104***	-0.486***	-0.182***
	(-5.19)	(-5.79)	(-5.12)	(-5.61)
Lithium-based Battery $_{(it)}$	0.001	0.000	0.059	0.023
	(0.01)	(0.01)	(1.11)	(1.11)
Nickel-based Battery $_{(it)}$	0.186***	0.065***	0.135**	0.054**
	(3.22)	(3.11)	(1.92)	(1.92)
ZincAir-based Battery $_{(it)}$	-0.436**	-0.126***	-1.048***	-0.334***
	(-2.16)	(-2.62)	(-4.78)	(-7.35)
Institutional logic effects				
Environmental Protest $_{(t-2)}$	0.010***	0.004***	0.122***	0.049***
	(3.06)	(3.07)	(8.69)	(8.70)
US Unemployment $_{(t-2)}$ (%)	0.082**	0.027**	-1.189***	-0.471***
	(2.23)	(2.24)	(-9.99)	(-10.00)
Δ Environmental Logic $_{(t-2)}$	0.000	0.000	0.021***	0.008***
	(-1.17)	(-1.17)	(6.95)	(6.96)
Δ Industrial Logic $_{(t-2)}$	-0.003***	-0.001***	-0.026***	-0.010***
	(-5.09)	(-5.10)	(-6.54)	(-6.54)
Main effects				
Cohesion Networks	-0.090***	-0.030***	0.807***	0.320***
Industrial Logic $_{(t-2)}$	(-8.50)	(-8.68)	(7.75)	(7.75)
Constant	-0.635**		-2.538***	
	(-2.45)		(-5.31)	
N	6154		5267	
Log Likelihood	-3342.410		-3206.226	

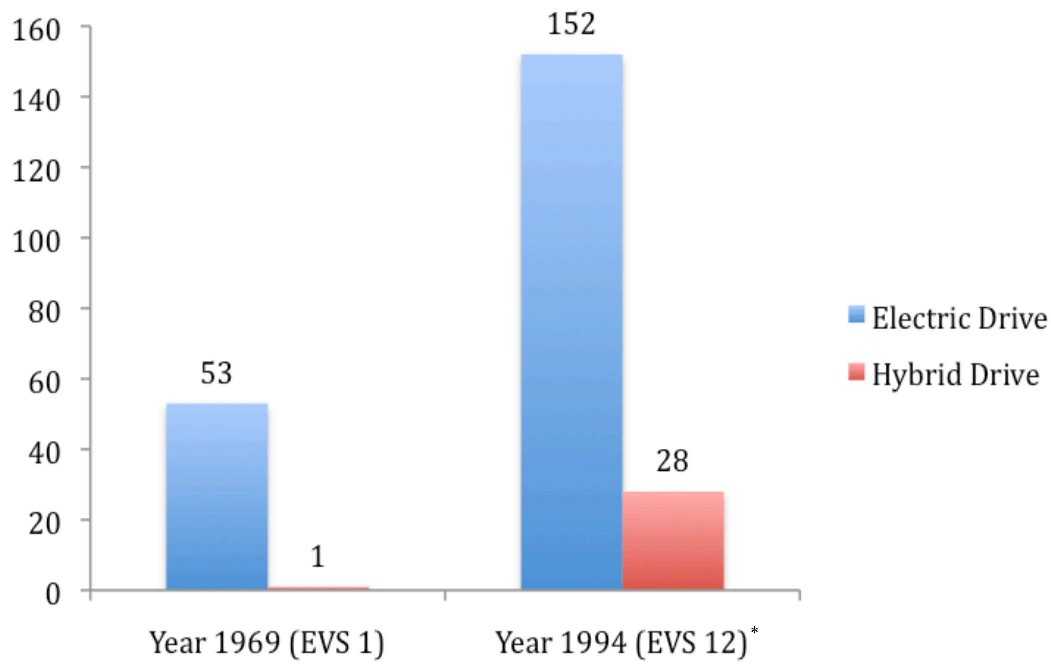
*: p < .10; **: p < .05; ***: p < .01 (one-tailed test)
t-statistics in parentheses; robust standard errors used
†: In the case of low COHESION NETWORKS ENVIRONMENTAL LOGIC (model 10), a specification with the variables of Δ US CAR PRICE and Δ CO_2 EMISSION could not be identified because of multicolinearity. Thus, the two variables are excluded in both models 9 and 10 to compare the marginal effects across specifications.

Table 9. Multivariate vs. Univariate Probit Regressions

Variable	Equation 1 DV = Industrial logic $_{(it)}$ Multivariate probit§ (β)	Equation 1 DV = Industrial logic $_{(it)}$ Univariate probit (β)	Equation 2 DV = Environmental logic $_{(it)}$ Multivariate probit (β)	Equation 2 DV = Environmental logic $_{(it)}$ Univariate probit (β)	Equation 3 DV = Electric drive $_{(it)}$ Multivariate probit (β)	Equation 3 DV = Electric drive $_{(it)}$ Univariate probit (β)	Equation 4 DV = Hybrid drive $_{(it)}$ Multivariate probit (β)	Equation 4 DV = Hybrid drive $_{(it)}$ Univariate probit (β)
Environmental Protest $_{(t-2)}$	-0.008*** (-2.69)	-0.008*** (-2.62)	0.003* (1.42)	0.002 (1.25)				
US Unemployment $_{(t-2)}$ (%)	0.045** (1.81)	0.048** (1.94)	-0.048*** (-3.09)	-0.046*** (-2.94)				
Cohesion Networks Environmental Logic $_{(t-2)}$					0.031*** (10.69)	0.039*** (9.50)	-0.021*** (-8.21)	-0.026*** (-8.19)
Cohesion Networks Industrial Logic $_{(t-2)}$					-0.061*** (-4.76)	-0.072*** (-4.71)	0.026** (2.13)	0.032*** (2.42)
Control Variables†	Included	Included	Included	Included	Included	Included	Included	Included
ρ_{21}	-0.762*** (-54.66)							
ρ_{31}	0.012 (0.53)							
ρ_{41}	0.055** (2.28)							
ρ_{32}	-0.317*** (-20.65)							
ρ_{42}	0.279*** (18.30)							
ρ_{43}	-0.984*** (-586.19)							
N	11421	11421	11421	11421	11421	11421	11421	11421

*: p < .10; **: p < .05; ***: p < .01 (one-tailed test)
t-statistics in parentheses; robust standard error used
†: Control variables in table 6 are included in equations 1 and 2; control variables in table 7 are included in equations 3 and 4
§: Maximum simulated likelihood estimation; Geweke–Hajivassilou–Keane simulator with 100 draws.

Figure 5. Total Number of Papers Covering Electric and Hybrid Drives



* Out of 172 papers, 8 papers (= 152 + 28 - 172) discussed both electric and hybrid drives in 1994

Table 10. Frequency of Keywords in Institutional Logics

Institutional Logics	Year 1969 (EVS 1)*			Year 1994 (EVS 12)**		
	Key words	Freq.	%	Key words	Freq.	%
Industrial logic	Power	608	0.50	Charging	2,464	0.60
	Speed	514	0.40	Power	2,489	0.60
	Cost	345	0.30	Batteries	1,392	0.30
	Time	266	0.20	Range	995	0.20
	Control	261	0.20	Performance	940	0.20
	Batteries	247	0.20	Speed	814	0.20
	Charging	183	0.20	Control	795	0.20
	Range	172	0.10	Time	747	0.20
	Performance	152	0.10	Cost	814	0.20
	Efficiency	130	0.10	Efficiency	697	0.20
	Economic	97	0.10	Consumer	360	0.10
	Market	93	0.10	Market	299	0.10
	Demand	83	0.10	Infrastructure	261	0.10
Total papers		53			153	
Total word counts		133,292			399,285	
Environmental Logic	Air	113	0.20	Emissions	577	0.30
	People	77	0.10	Safety	242	0.20
	Pollution	63	0.10	Air	216	0.10
	Land	51	0.10	Environment	194	0.10
	Travel	45	0.10			
	Trip	30	0.10			
Total papers		16			63	
Total word counts		56,681			156,071	

* In 1969, 54 papers were published. When a paper covers both environmental and industrial logics, the paper is included when counting keywords for the environmental and industrial logics. In total 15 (= 53 + 16 - 54) papers used both logics.
** In 1994, 172 papers were published. Similarly, when a paper covers both environmental and industrial logics, the paper is included when counting keywords for the environmental and industrial logics. In total, 44 (= 153 + 63 - 172) papers adopted both logics.

Table 11. Similarity Matrix of Institutional Logics in 1969

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(1) Air	1.00																	
(2) Battery	0.11	1.00																
(3) Charging	0.03	0.14	1.00															
(4) Control	0.06	0.07	0.09	1.00														
(5) Cost	0.10	0.10	0.06	0.14	1.00													
(6) Demand	0.10	0.01	0.07	0.03	0.06	1.00												
(7) Economic	0.06	0.04	0.04	0.04	0.11	0.04	1.00											
(8) Efficiency	0.01	0.04	0.05	0.10	0.02	0.06	0.03	1.00										
(9) Land	0.03	0.01	0.00	0.00	0.05	0.01	0.04	0.00	1.00									
(10) Market	0.02	0.03	0.01	0.02	0.04	0.07	0.03	0.00	0.00	1.00								
(11) People	0.09	0.01	0.03	0.03	0.04	0.03	0.06	0.01	0.08	0.04	1.00							
(12) Performance	0.06	0.16	0.06	0.08	0.11	0.02	0.04	0.07	0.01	0.03	0.03	1.00						
(13) Pollution	0.24	0.01	0.01	0.05	0.07	0.02	0.03	0.00	0.06	0.00	0.13	0.04	1.00					
(14) Power	0.08	0.23	0.07	0.15	0.15	0.03	0.03	0.11	0.00	0.03	0.01	0.13	0.05	1.00				
(15) Range	0.06	0.12	0.07	0.10	0.10	0.03	0.03	0.11	0.01	0.05	0.03	0.17	0.03	0.16	1.00			
(16) Speed	0.04	0.16	0.06	0.20	0.07	0.03	0.03	0.10	0.01	0.01	0.02	0.13	0.01	0.33	0.16	1.00		
(17) Time	0.07	0.07	0.14	0.08	0.08	0.08	0.06	0.04	0.02	0.03	0.10	0.08	0.03	0.10	0.07	0.11	1.00	
(18) Travel	0.05	0.01	0.02	0.02	0.04	0.13	0.04	0.01	0.05	0.01	0.06	0.04	0.04	0.01	0.05	0.04	0.05	1.00
(19) Trip	0.01	0.03	0.04	0.01	0.05	0.04	0.05	0.00	0.04	0.02	0.15	0.03	0.02	0.03	0.08	0.05	0.11	0.11

Table 12. Similarity Matrix of Institutional Logics in 1994

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
(1) Air	1.00																
(2) Batteries	0.04	1.00															
(3) Charging	0.02	0.12	1.00														
(4) Consumer	0.03	0.03	0.03	1.00													
(5) Control	0.06	0.03	0.06	0.03	1.00												
(6) Cost	0.04	0.14	0.05	0.07	0.04	1.00											
(7) Efficiency	0.11	0.04	0.07	0.01	0.11	0.03	1.00										
(8) Emission	0.11	0.02	0.02	0.03	0.03	0.03	0.08	1.00									
(9) Environment	0.08	0.05	0.02	0.05	0.02	0.07	0.04	0.08	1.00								
(10) Infrastructure	0.02	0.02	0.04	0.09	0.01	0.05	0.01	0.02	0.04	1.00							
(11) Market	0.03	0.04	0.02	0.11	0.01	0.12	0.01	0.03	0.08	0.11	1.00						
(12) Performance	0.07	0.14	0.05	0.04	0.08	0.12	0.11	0.06	0.07	0.03	0.07	1.00					
(13) Power	0.08	0.16	0.19	0.03	0.15	0.07	0.12	0.08	0.03	0.03	0.02	0.14	1.00				
(14) Range	0.10	0.14	0.08	0.05	0.08	0.09	0.13	0.06	0.05	0.02	0.06	0.19	0.14	1.00			
(15) Safety	0.02	0.04	0.03	0.04	0.04	0.05	0.01	0.02	0.05	0.04	0.04	0.04	0.03	0.03	1.00		
(16) Speed	0.06	0.04	0.03	0.02	0.15	0.04	0.15	0.03	0.03	0.00	0.01	0.13	0.14	0.19	0.03	1.00	
(17) Time	0.05	0.10	0.15	0.09	0.08	0.07	0.06	0.04	0.07	0.04	0.06	0.08	0.12	0.11	0.04	0.08	1.00
(18) Utility	0.03	0.02	0.05	0.13	0.04	0.04	0.01	0.02	0.04	0.15	0.05	0.02	0.05	0.05	0.02	0.01	0.07

Figure 6. Dendrogram of Institutional Logics in 1969

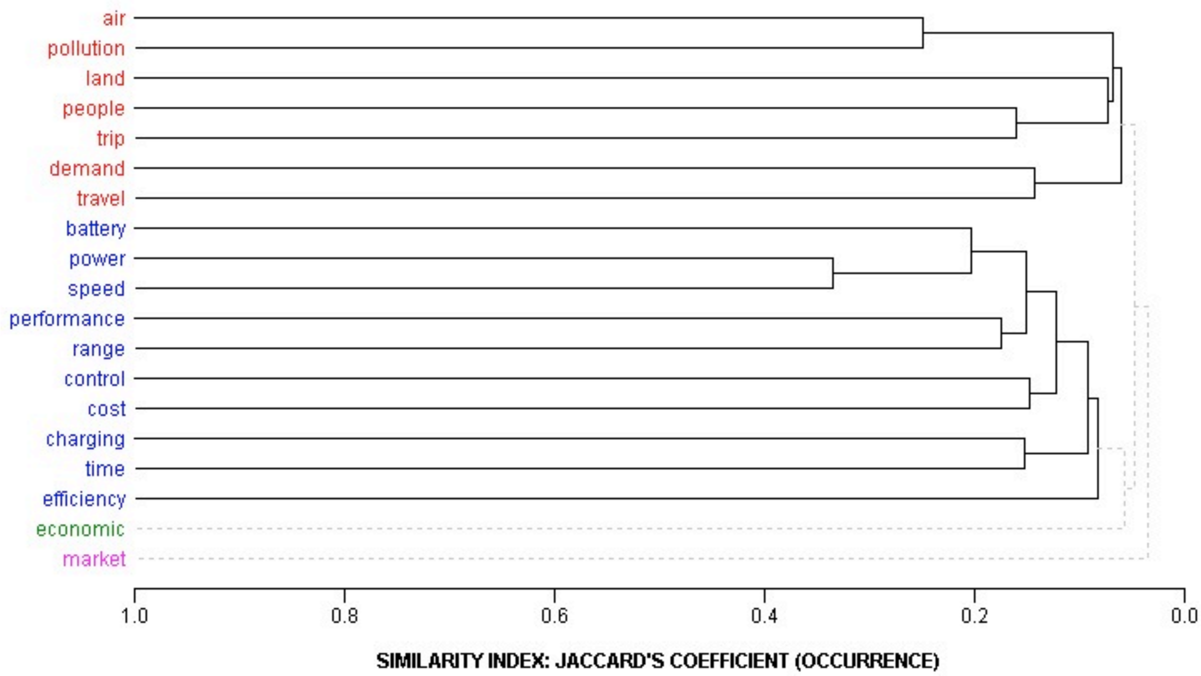


Figure 7. Dendrogram of Institutional Logics in 1994

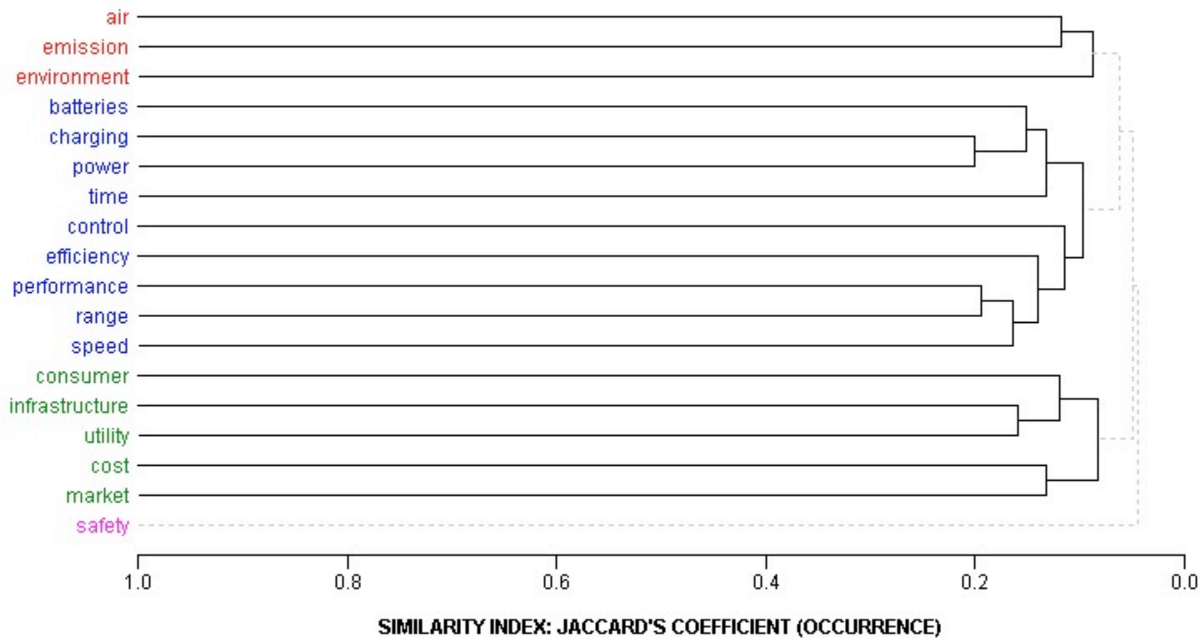
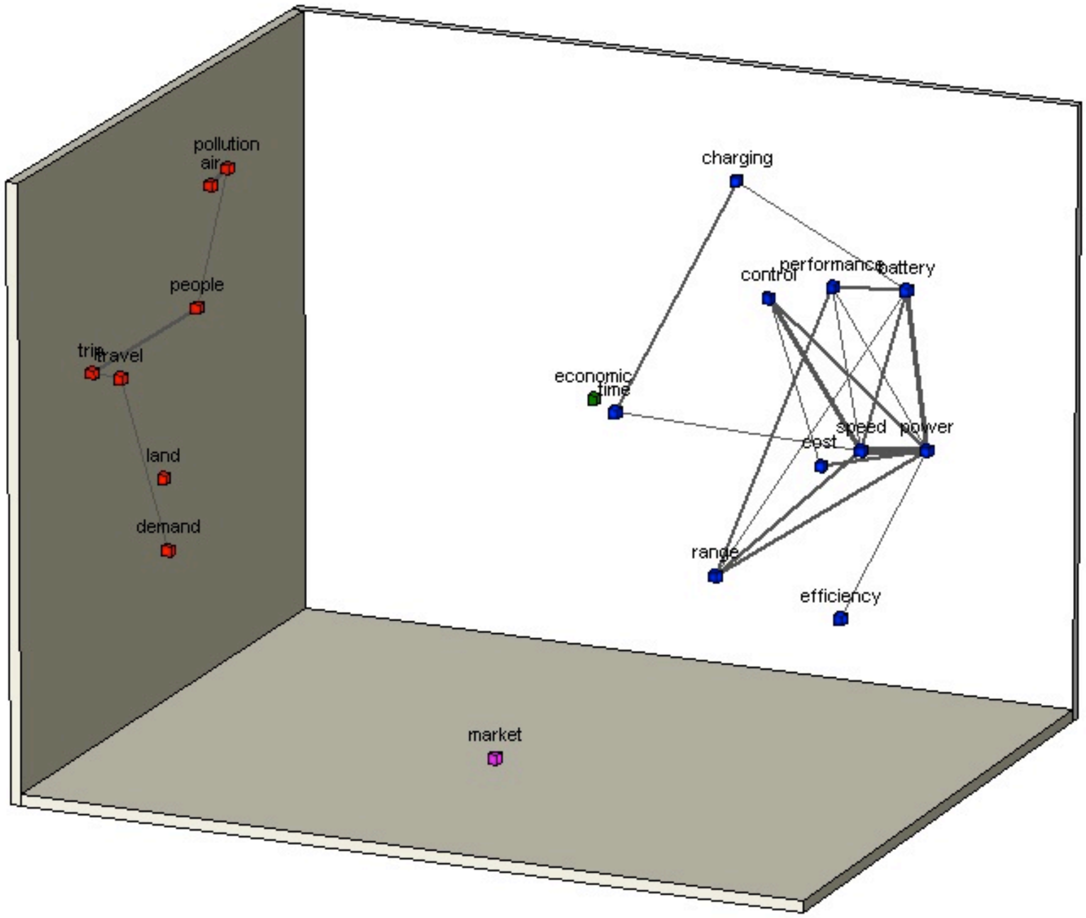
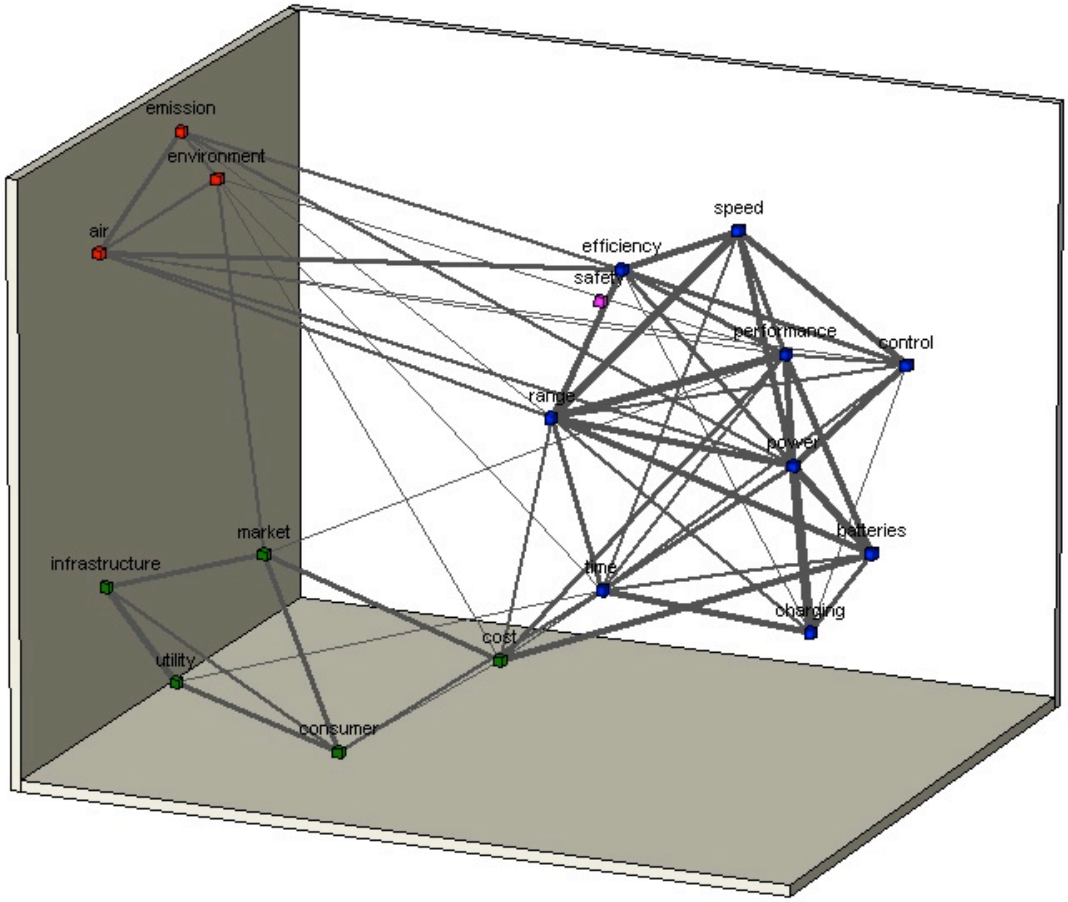


Figure 8. MDS of Environmental and Industrial Logics in 1969



Stress level = 0.1925; R^2 = 0.8770

Figure 9. MDS of Environmental and Industrial Logics in 1994



Stress Level = 0.1869; R^2 = 0.9036

Bibliography

Abrahamson, Eric and Micki Eisenman. 2008. "Employee-management Techniques: Transient Fads or Trending Fashions?" *Administrative Science Quarterly* 53:719-744.

Abrahamson, Eric and Gregory Fairchild. 1999. "Management Fashion: Lifecycles, Triggers, and Collective Learning Processes." *Administrative Science Quarterly* 44:708-740.

Adler, Paul S. 2005. "The Evolving Object of Software Development." *Organization* 12:401-435.

Akrich, Madeleine. 1992. "The De-scription of Technical Objects." Pp. 205-224 in *Shaping Technology/Building Society: Studies in Sociotechnical Change*, edited by W. E. Bijker and J. Law. Cambridge, MA: MIT Press.

Aldrich, Howard E. and C. Marlene Fiol. 1994. "Fools Rush in? The Institutional Context of Industry Creation." *Academy of Management Review* 19:645-670.

Alexander, Jeffrey C. and Bernhard Giesen. 1987. "From Reduction to Linkage: The Long View of the Micro-Macro Debate." Pp. 1-42 in *The Micro-Macro Link*, edited by J. C. Alexander, B. Giesen, R. Münch, and N. J. Smelser. Berkeley and Los Angeles, CA: University of California Press.

Alford, Robert R. and Roger Friedland. 1985. *Powers of Theory: Capitalism, the State, and Democracy.* New York: Cambridge University Press.

Anderson, Curtis D. and Judy Anderson. 2010. *Electric and Hybrid Cars: A History*. Jefferson, NC: McFarland & Company, Inc.

Anderson, Philip and Michael L. Tushman. 1990. "Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change." *Administrative Science Quarterly* 35:604-633.

Arthur, W. Brian. 1989. "Competing Technologies, Increasing Returns, and Lock-in by Historical Events." *Economic Journal* 99:116-131.

—. 1994. *Increasing Returns and Path Dependence in the Economy*. Ann Arbor, MI: University of Michigan Press.

Barley, Stephen R. 1986. "Technology as an Occasion for Structuring: Evidence from Observations of CT Scanners and the Social Order of Radiology Departments." *Administrative Science Quarterly* 31:78-108.

Barley, Stephen R. and Pamela S. Tolbert. 1997. "Institutionalization and Structuration: Studying the Links between Action and Institution." *Organization Studies* 18:93-117.

Benford, Robert D. and David A. Snow. 2000. "Framing Processes and Social Movements: An Overview and Assessment." *Annual Review of Sociology* 26:611-639.

Berger, Jonah A. and Chip Heath. 2005. "Idea Habitats: How the Prevalence of Environmental Cues Influences the Success of Ideas." *Cognitive Science* 29:195-221.

Berger, Michael L. 1979. *The Devil Wagon in God's Country: The Automobile and Social Change in Rural America, 1893-1929*. Hamden, CT: Archon Books.

Berger, Peter L., Brigitte Berger, and Hansfried Kellner. 1973. *The Homeless Mind: Modernization and Consciousness*. New York: Random House.

Berger, Peter L. and Thomas Luckmann. 1967. *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*. New York: Doubleday.

Bhattacharya, Jay, Dana Goldman, and Daniel McCaffrey. 2006. "Estimating Probit Models with Self-selected Treatments." *Statistics in Medicine* 25:389-413.

Biggart, Nicole Woolsey and Thomas D. Beamish. 2003. "The Economic Sociology of Conventions: Habit, Custom, Practice, and Routine in Market Order." *Annual Review of Sociology* 29:443-464.

Bijker, Wiebe E. 1987. "The Social Construction of Bakelite: Toward a Theory of Invention." Pp. 159-187 in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, edited by W. E. Bijker, T. P. Hughes, and T. J. Pinch. Cambridge, MA: MIT Press.

Bockris, J O'M. 1971. "The Electrochemical Future." Pp. 8-14 in *International Electric Vehicle Symposium*, vol. 2. Atlantic City, NJ: International Electric Vehicle Symposium.

Bourdieu, Pierre. 1996. *The Rules of Art: Genesis and Structure of the Literary Field*. Translated by S. Emanuel. Stanford, CA: Stanford University Press.

Bresnahan, Timothy F. 1987. "Competition and Collusion in the American Automobile Industry: The 1955 Price War." *Journal of Industrial Economics* 35:457-482.

Brown, John Seely and Paul Duguid. 1991. "Organizational Learning and Communities-of-Practice: Toward a Unified View of Working, Learning, and Innovating." *Organization Science* 2:40-57.

Burt, Ronald S. 2005. *Brokerage & Closure: An Introduction to Social Capital*. New York: Oxford University Press.

Callon, Michel. 1987. "Society in the Making: The Study of Technology as a Tool for Sociological Analysis." Pp. 83-103 in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, edited by W. E. Bijker, T. P. Hughes, and T. J. Pinch. Cambridge, MA: MIT Press.

Cameron, A. Colin and Pravin K. Trivedi. 2005. *Microeconometrics: Methods and Applications*. New York: Cambridge University Press.

Camic, Charles. 1986. "The Matter of Habit." *American Journal of Sociology* 91:1039-1087.

Carlile, Paul R. 2002. "A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development." *Organization Science* 13:442-455.

Carlson, W. Bernard. 1994. "Artifacts and Frames of Meaning: Thomas A. Edison, His Managers, and the Cultural Construction of Motion Pictures." Pp. 175-198 in

Shaping Technology/Building Society: Studies in Sociotechnical Change, edited by W. E. Bijker and J. Law. Cambridge, MA: MIT Press.

Carson, Rachel L. 1962. *Silent Spring*. New York: Houghton Mifflin Company.

Carter, Nancy M. 1984. "Computerization as a Predominate Technology: Its Influence on the Structure of Newspaper Organizations." *Academy of Management Journal* 27:247-270.

Chenery, Hollis B., Sherman Robinson, and Moshe Syrquin. 1986. *Industrialization and Growth: A Comparative Study*. New York: Oxford University Press.

Clemens, Elisabeth S. 1993. "Organizational Repertoires and Institutional Change: Women's Groups and the Transformation of U.S. Politics, 1890-1920." *American Journal of Sociology* 98:755-798.

Cohen, Wesley M. and Richard C. Levin. 1989. "Empirical Studies of Innovation and Market Structure." Pp. 1059-1107 in *Handbook of Industrial Organization*, vol. 2, edited by R. Schmalensee and R. D. Willig. New York: North-Holland.

Dacin, M. Tina. 1997. "Isomorphism in Context: The Power and Prescription of Institutional Norms." *Academy of Management Journal* 40:46-81.

David, Paul A. 1985. "Clio and the Economics of QWERTY." *American Economic Review* 75:332-337.

Davis, Gerald F. and Tracy A. Thompson. 1994. "A Social Movement Perspective on Corporate Control." *Administrative Science Quarterly* 39:141-173.

Davis, Louis E. and James C. Taylor. 1976. "Technology, Organization, and Job Structure." Pp. 379-419 in *Handbook of Work, Organization, and Society*, edited by R. Dubin. Chicago: Rand-McNally.

DiMaggio, Paul J. 1988. "Interest and Agency in Institutional Theory." Pp. 3-21 in *Institutional Patterns and Organizations: Culture and Environment*, edited by L. G. Zucker. Cambridge, MA: Ballinger.

DiMaggio, Paul J. and Walter W. Powell. 1983. "The Iron Cage Revisited: Institutional Isomorphism and Collective Rationality in Organizational Fields." *American Sociological Review* 48:147-160.

—. 1991. "Introduction." Pp. 1-38 in *The New Institutionalism in Organizational Analysis*, edited by W. W. Powell and P. J. DiMaggio. Chicago, IL: University of Chicago Press.

Dougherty, Deborah. 1992. "Interpretive Barriers to Successful Product Innovation in Large Firms." *Organization Science* 3:179-202.

Dowell, Glen, Anand Swaminathan, and James Wade. 2002. "Pretty Pictures and Ugly Scenes: Political and Technological Maneuvers in High Definition Television." *Advances in Strategic Management* 19:97-133.

Dunn, Mary B. and Candace Jones. 2010. "Institutional Logics and Institutional Pluralism: The Contestation of Care and Science Logics in Medical Education, 1967--2005." *Administrative Science Quarterly* 55:114-149.

Earl, Jennifer, Andrew Martin, John D. McCarthy, and Sarah A. Soule. 2004. "The Use of Newspaper Data in the Study of Collective Action." *Annual Review of Sociology* 30:65-80.

Earl, Jennifer and Sarah A. Soule. 2006. "Seeing Blue: A Police-centered Explanation of Protest Policing." *Mobilization: An International Quarterly* 11:145-164.

Elsbach, Kimberly D. 1994. "Managing Organizational Legitimacy in the California Cattle Industry: The Construction and Effectiveness of Verbal Accounts." *Administrative Science Quarterly* 39:57-88.

Farrell, Joseph and Garth Saloner. 1985. "Standardization, Compatibility, and Innovation." *RAND Journal of Economics* 16:70-83.

Fligstein, Neil. 1985. "The Spread of the Multidivisional Form among Large Firms, 1919-1979." *American Sociological Review* 50:377-391.

—. 1997. "Social Skill and Institutional Theory." *American Behavioral Scientist* 40:397-405.

—. 2001. "Social Skill and the Theory of Fields." *Sociological Theory* 19:105-125.

Fligstein, Neil and Doug McAdam. 2011. "Toward a General Theory of Strategic Action Fields." *Sociological Theory* 29:1-26.

Foucault, Michel. 1980. *Power/knowledge: Selected Interviews and Other Writings, 1972-1977*, Edited by C. Gordon. Translated by C. Gordon. New York: Pantheon.

Friedland, Roger and Robert R. Alford. 1991. "Bringing Society Back in: Symbols, Practices, and Institutional Contradictions." Pp. 232-263 in *The New Institutionalism in Organizational Analysis*, edited by W. W. Powell and P. J. DiMaggio. Chicago, IL: University of Chicago Press.

Galbraith, Jay R. 1977. *Organizational Design*. Reading, MA: Addison-Wesley.

Garud, Raghu, Cynthia Hardy, and Steve Maguire. 2007. "Institutional Entrepreneurship as Embedded Agency: An Introduction to the Special Issue." *Organization Studies* 28:957-969.

Garud, Raghu, Sanjay Jain, and Arun Kumaraswamy. 2002. "Institutional Entrepreneurship in the Sponsorship of Common Technological Standards: The Case of Sun Microsystems and Java." *Academy of Management Journal* 45:196-214.

Garud, Raghu and Peter Karnøe. 2001. "Path Creation as a Process of Mindful Deviation." Pp. 1-38 in *Path Dependence and Creation*, edited by R. Garud and P. Karnøe. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Garud, Raghu and Arun Kumaraswamy. 1995. "Coupling the Technical and Institutional Faces of Janus in Network Industries." Pp. 226-242 in *The Institutional Construction of Organizations: International and Longitudinal Studies*, edited by W. R. Scott and S. Christensen. Thousand Oaks, CA: SAGE.

Garud, Raghu and Michael A. Rappa. 1994. "A Socio-cognitive Model of Technology Evolution: The Case of Cochlear Implants." *Organization Science* 5:344-362.

Geweke, John, Michael Keane, and David Runkle. 1994. "Alternative Computational Approaches to Inference in the Multinomial Probit Model." *Review of Economics and Statistics* 76:609-632.

Giddens, Anthony. 1979. *Central Problems in Social Theory: Action, Structure and Contradiction in Social Analysis*. Berkeley and Los Angeles, CA: University of California Press.

—. 1984. *The Constitution of Society: Outline of the Theory of Structure*. Berkeley and Los Angeles, CA: University of California Press.

Glynn, Mary Ann and Michael Lounsbury. 2005. "From the Critics' Corner: Logic Blending, Discursive Change and Authenticity in a Cultural Production System." *Journal of Management Studies* 42:1031-1055.

Gottlieb, Robert. (1993) 2005. *Forcing the Spring: The Transformation of the American Environmental Movement*. Washington, DC: Island Press.

Granovetter, Mark and Patrick McGuire. 1998. "The Making of an Industry: Electricity in the United States." Pp. 147-173 in *The Laws of the Market*, edited by M. Callon. Oxford, UK: Blackwell Publishers.

Greene, William H. 2003. *Econometric Analysis*. Upper Saddle River, NJ: Prentice Hall.

Greenwood, Royston, Amalia Magán Díaz, Stan Xiao Li, and José Céspedes Lorente. 2010. "The Multiplicity of Institutional Logics and the Heterogeneity of Organizational Responses." *Organization Science* 21:521-539.

Greenwood, Royston, C. R. Hinings, and Roy Suddaby. 2002. "Theorizing Change: The Role of Professional Associations in the Transformation of Institutionalized Fields." *Academy of Management Journal* 45:58-80.

Greenwood, Royston and Roy Suddaby. 2006. "Institutional Entrepreneurship in Mature Fields: The Big Five Accounting Firms." *Academy of Management Journal* 49:27-48.

Grodal, Stine. 2010. "Categorizing a Field: The Use of the Nanotechnology Label across Communities." Boston, MA: Working Paper, Boston University.

Hallen, Benjamin L. 2008. "The Causes and Consequences of the Initial Network Positions of New Organizations: From Whom Do Entrepreneurs Receive Investments?" *Administrative Science Quarterly* 53:685-718.

Hallen, Benjamin L. and Kathleen M. Eisenhardt. 2011. "Catalyzing Strategies: How Entrepreneurs Accelerate Inter-Organizational Relationship Formation to Secure Professional Investments." College Park, MD: Working Paper, University of Maryland.

Hargadon, Andrew B. and Yellowlees Douglas. 2001. "When Innovations Meet Institutions: Edison and the Design of the Electric Light." *Administrative Science Quarterly* 46:476-501.

Hargrave, Timothy J. and Andrew H. Van De Ven. 2006. "A Collective Action

Model of Institutional Innovation." *Academy of Management Review* 31:864-888.

Haring, Kristen. 2007. *Ham Radio's Technical Culture*. Cambridge, MA: MIT Press.

Harvey, Edward. 1968. "Technology and the Structure of Organizations." *American Sociological Review* 33:247-259.

Hays, Samuel P. 1995. *The Response to Industrialism, 1885-1914*. Chicago, IL: University of Chicago Press.

Hirsch, Paul M. 1997. "Review: Sociology Without Social Structure: Neoinstitutional Theory Meets Brave New World." *American Journal of Sociology* 102:1702-1723.

Hoffman, Andrew J. 1999. "Institutional Evolution and Change: Environmentalism and the U.S. Chemical Industry." *Academy of Management Journal* 42:351-371.

Hoffman, George A. 1967. "Power Systems for Hybrid Electric Vehicles." Publication No. PHS.999-A.P.37, edited by U. S. H.E.W.

Hughes, Everett C. 1939. "Institutions." Pp. 283-346 in *An Outline of the Principles of Sociology*, edited by R. E. Park. New York: Barnes and Noble.

Hughes, Thomas P. 1987. "The Evolution of Large Technological Systems." Pp. 51-82 in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, edited by W. E. Bijker, T. P. Hughes, and T. J. Pinch. Cambridge, MA: MIT Press.

Hulin, Charles L. and M. Roznowski. 1985. "Organizational Technologies: Effects on Organizations' Characteristics and Individuals' Responses." *Research in Organizational Behavior* 7:39-85.

Ingram, Paul, Lori Qingyuan Yue, and Hayagreeva Rao. 2010. "Trouble in Store: Probes, Protests, and Store Openings by Wal-Mart, 1998-2007." *American Journal of Sociology* 116:53-92.

Isserman, Maurice and Michael Kazin. 2004. *America Divided: The Civil War of the 1960s*. New York: Oxford University Press.

Jarzabkowski, Paula. 2008. "Shaping Strategy as a Structuration Process." *Academy of Management Journal* 51:621-650.

Jenkins, Stephen P., Lorenzo Cappellari, Peter Lynn, Annette Jäckle, and Emanuela Sala. 2006. "Patterns of Consent: Evidence from a General Household Survey." *Journal of the Royal Statistical Society: Series A (Statistics in Society)* 169:701-722.

Jepperson, Ronald L. 1991. "Institutions, Institutional Effects, and Institutionalism." Pp. 143-163 in *The New Institutionalism in Organizational Analysis*, edited by W. W. Powell and P. J. DiMaggio. Chicago, IL: University of Chicago Press.

Jones, Candace and Reut Livne-Tarandach. 2008. "Designing a Frame: Rhetorical Strategies of Architects." *Journal of Organizational Behavior* 29:1075-1099.

Kabanoff, Boris. 1997. "Introduction: Computers Can Read as Well as Count: Computer-Aided Text Analysis in Organizational Research." *Journal of Organizational Behavior* 18:507-511.

Kaplan, Sarah and Fiona Murray. 2010. "Entrepreneurship and the Construction of Value in Biotechnology." Pp. 107-147 in *Research in the Sociology of Organizations (Technology and Organization: Essays in Honour of Joan Woodward)*, vol. 29, edited by N. Phillips, G. Sewell, and D. Griffiths. Bingley, UK: Emerald Group Publishing Limited.

Kaplan, Sarah and Mary Tripsas. 2008. "Thinking about Technology: Applying a Cognitive Lens to Technical Change." *Research Policy* 37:790-805.

Katz, Michael L. and Carl Shapiro. 1986. "Technology Adoption in the Presence of Network Externalities." *Journal of Political Economy* 94:822-841.

Kennedy, Mark Thomas. 2008. "Getting Counted: Markets, Media, and Reality." *American Sociological Review* 73:270-295.

Kennedy, Mark Thomas and Peer Christian Fiss. 2009. "Institutionalization, Framing, and Diffusion: The Logic of TQM Adoption and Implementation Decisions among U.S. Hospitals." *Academy of Management Journal* 52:897-918.

Khazam, Jonathan and David Mowery. 1994. "The Commercialization of RISC: Strategies for the Creation of Dominant Designs." *Research Policy* 23:89-102.

Kimes, Beverly R. and Henry Austin Clark. 1996. *Standard Catalog of American Cars 1805-1942*. Iola, WI: Krause Publications.

King, Brayden G. and Sarah A. Soule. 2007. "Social Movements as Extra-institutional Entrepreneurs: The Effect of Protests on Stock Price Returns." *Administrative Science Quarterly* 52:413-442.

Kirsch, David A. 1996. "The Electric Car and the Burden of History: Studies in Automotive Systems Rivalry in America, 1890-1996.". Unpublished Dissertation, Stanford: Stanford University.

—. 2000. *The Electric Vehicle and the Burden of History*. New Brunswick, NJ: Rutgers University Press.

Kirzner, Israel M. 1973. *Competition and Entrepreneurship*. Chicago, IL: University of Chicago Press.

Klein, Hans K. and Daniel Lee Kleinman. 2002. "The Social Construction of Technology: Structural Considerations." *Science, Technology, & Human Values* 27:28-52.

Kline, Ronald and Trevor J. Pinch. 1996. "Users as Agents of Technological Change: The Social Construction of the Automobile in the Rural United States." *Technology and Culture* 37:763-795.

Knight, Jack. 1992. *Institutions and Social Conflict*. New York: Cambridge University Press.

Könnölä, Totti, Gregory C. Unruh, and Javier Carrillo-Hermosilla. 2006. "Prospective Voluntary Agreements for Escaping Techno-institutional Lock-in." *Ecological Economics* 57:239-252.

Kraatz, Matthew S. 1998. "Learning by Association? Interorganizational Networks and Adaptation to Environmental Change." *Academy of Management Journal* 41:621-643.

Kraatz, Matthew S. and Emily S. Block. 2008. "Organizational Implications of Institutional Pluralism." Pp. 243-275 in *The SAGE Handbook of Organizational Institutionalism*, edited by R. Greenwood, C. Oliver, K. Sahlin, and R. Suddaby. Los Angeles, CA: SAGE.

Kraatz, Matthew S. and Edward J. Zajac. 1996. "Exploring the Limits of the New Institutionalism: The Causes and Consequences of Illegitimate Organizational Change." *American Sociological Review* 61:812-836.

Krippendorff, Klaus. 2004. *Content Analysis: An Introduction to Its Methodology*. Thousand Oaks, CA: Sage Publications, Inc.

Kuhn, Thomas S. 1970. *The Structure of Scientific Revolutions*. Chicago, IL: University of Chicago.

Lampel, Joseph. 2001. "Show-and-Tell: Product Demonstrations and Path Creation of Technological Change." Pp. 303-327 in *Path Dependence and Creation*, edited by R. Garud and P. Karnøe. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Lampel, Joseph and Alan D. Meyer. 2008. "Guest Editors' Introduction: Field-Configuring Events as Structuring Mechanisms: How Conferences, Ceremonies, and Trade Shows Constitute New Technologies, Industries, and Markets." *Journal of Management Studies* 45:1025-1035.

Latour, Bruno. 1987. *Science in Action: How To Follow Scientists and Engineers through Society*. Cambridge, MA: Harvard University Press.

Lave, Jean and Etienne Wenger. 1991. *Situated Learning: Legitimate Peripheral Participation*. New York: Cambridge University Press.

Law, John. 2000. "On the Subject of the Object: Narrative, Technology, and Interpellation." *Configurations* 8:1-30.

Lounsbury, Michael. 2007. "A Tale of Two Cities: Competing Logics and Practice Variation in the Professionalizing of Mutual Funds." *Academy of Management Journal* 50:289-307.

Lounsbury, Michael and Mary Ann Glynn. 2001. "Cultural Entrepreneurship: Stories, Legitimacy, and the Acquisition of Resources." *Strategic Management Journal* 22:545-564.

Lounsbury, Michael, Marc Ventresca, and Paul M. Hirsch. 2003. "Social Movements, Field Frames and Industry Emergence: A Cultural-political Perspective on US Recycling." *Socio-Economic Review* 1:71-104.

Lucking, Walter T. 1971. "Opening Comments." Pp. 2-7 in *International Electric Vehicle Symposium*, vol. 2. Atlantic City, NJ: International Electric Vehicle Symposium.

MacKenzie, Donald. 1987. "Missile Accuracy: A Case Study in the Social Processes of Technological Change." Pp. 195-222 in *The Social Construction of Technological*

Systems: New Directions in the Sociology and History of Technology, edited by W. E. Bijker, T. P. Hughes, and T. J. Pinch. Cambridge, MA: MIT Press.

Maddala, G. S. 1986. *Limited Dependent and Qualitative Variables in Econometrics*. Cambridge, UK: Cambridge University Press.

Maguire, Steve and Cynthia Hardy. 2009. "Discourse and Deinstitutionalization: The Decline of DDT." *Academy of Management Journal* 52:148-178.

Mannheim, Karl. 1937. *Ideology and Utopia: An Introduction to the Sociology of Knowledge*. Translated by L. Wirth and E. Shils. New York: Harcourt.

Marquis, Christopher and Michael Lounsbury. 2007. "Vive La résistance: Competing Logics and the Consolidation of U.S. Community Banking." *Academy of Management Journal* 50:799-820.

McAdam, Doug and W. Richard Scott. 2005. "Organizations and Movements." Pp. 4-40 in *Social Movements and Organization Theory*, edited by G. F. Davis, D. McAdam, W. R. Scott, and M. N. Zald. New York: Cambridge University Press.

McCarthy, John D. and Mayer N. Zald. 1977. "Resource Mobilization and Social Movements: A Partial Theory." *American Journal of Sociology* 82:1212-1241.

Meyer, John W. and Brian Rowan. 1977. "Institutionalized Organizations: Formal Structure as Myth and Ceremony." *American Journal of Sociology* 83:340-363.

Mom, Gijs. 2004. *The Electric Vehicle: Technology and Expectations in the Automobile Age*. Baltimore, MD: Johns Hopkins University Press.

Mom, Gijs P. A. and David A. Kirsch. 2001. "Technologies in Tension: Horses, Electric Trucks, and the Motorization of American Cities, 1900-1925." *Technology and Culture* 42:489-518.

Munir, Kamal A. and Nelson Phillips. 2005. "The Birth of the 'Kodak Moment': Institutional Entrepreneurship and the Adoption of New Technologies." *Organization Studies* 26:1665-1687.

Murmann, Johann Peter and Koen Frenken. 2006. "Toward a Systematic Framework for Research on Dominant Designs, Technological Innovations, and Industrial Change." *Research Policy* 35:925-952.

Murphy, Kevin M., Andrei Shleifer, and Robert W. Vishny. 1989. "Industrialization and the Big Push." *Journal of Political Economy* 97:1003-1026.

Neuendorf, Kimberly A. 2002. *The Content Analysis Guidebook*. Thousand Oaks, CA: Sage Publications, Inc.

Neustadtl, Alan and Dan Clawson. 1988. "Corporate Political Groupings: Does Ideology Unify Business Political Behavior?" *American Sociological Review* 53:172-190.

North, Douglass C. 1990. *Institutions, Institutional Change, and Economic Performance*. New York: Cambridge University Press.

O'Mahony, Siobhán and Beth A. Bechky. 2008. "Boundary Organizations: Enabling Collaboration among Unexpected Allies." *Administrative Science Quarterly* 53:422-

459.

Oliver, Christine. 1991. "Strategic Responses to Institutional Processes." *Academy of Management Review* 16:145-179.

—. 1992. "The Antecedents of Deinstitutionalization." *Organization Studies* 13:563.

Orlikowski, Wanda J. 1992. "The Duality of Technology: Rethinking the Concept of Technology in Organizations." *Organization Science* 3:398-427.

Orlikowski, Wanda J. and Debra C. Gash. 1994. "Technological Frames: Making Sense of Information Technology in Organizations." *ACM Transactions on Information Systems* 12:174-207.

Orrù, Marco, Nicole Woolsey Biggart, and Gary G. Hamilton. 1991. "Organizational Isomorphism in East Asia." Pp. 361-389 in *The New Institutionalism in Organizational Analysis*, edited by W. W. Powell and P. J. DiMaggio. Chicago, IL: University of Chicago Press.

Palmer, Donald, Brad M. Barber, Xueguang Zhou, and Yasemin Soysal. 1995. "The Friendly and Predatory Acquisition of Large U.S. Corporations in the 1960s: The Other Contested Terrain." *American Sociological Review* 60:469-499.

Pepper, David. 1996. *Modern Environmentalism: An Introduction*. New York: Routledge.

Perrow, Charles. 1967. "A Framework for the Comparative Analysis of Organizations." *American Sociological Review* 32:194-208.

Phillips, Damon J. and Ezra W. Zuckerman. 2001. "Middle-status Conformity: Theoretical Restatement and Empirical Demonstration in Two Markets." *American Journal of Sociology* 107:379-429.

Phillips, Nelson, Thomas B. Lawrence, and Cynthia Hardy. 2004. "Discourse and Institutions." *Academy of Management Review* 29:635-652.

Phillips, Nelson and Namrata Malhotra. 2008. "Taking Social Construction Seriously: Extending the Discursive Approach in Institutional Theory." Pp. 702-720 in *The SAGE Handbook of Organizational Institutionalism*, edited by R. Greenwood, C. Oliver, K. Sahlin, and R. Suddaby. Los Angeles, CA: SAGE.

Pinch, Trevor J. 1996. "The Social Construction of Technology: A Review." Pp. 17-35 in *Technological Change: Methods and Themes in the History of Technology*, edited by R. Fox. Australia: Harwood Academic Publishers.

Pinch, Trevor J. and Wiebe E. Bijker. 1984. "The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." *Social Studies of Science (Sage)* 14:399-441.

—. 1987. "The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other." Pp. 17-50 in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, edited by W. E. Bijker, T. P. Hughes, and T. J. Pinch. Cambridge, MA: MIT Press.

Polanyi, Michael. 1946. *Science, Faith and Society*. Chicago, IL: University of Chicago Press.

Purdy, Jill M. and Barbara Gray. 2009. "Conflicting Logics, Mechanisms of Diffusion, and Multilevel Dynamics in Emerging Institutional Fields." *Academy of Management Journal* 52:355-380.

Rao, Hayagreeva. 1994. "The Social Construction of Reputation: Certification Contests, Legitimation, and the Survival of Organizations in the American Automobile Industry: 1895--1912." *Strategic Management Journal* 15:29-44.

Rao, Hayagreeva, Henrich R. Greve, and Gerald F. Davis. 2001. "Fool's Gold: Social Proof in the Initiation and Abandonment of Coverage by Wall Street Analysts." *Administrative Science Quarterly* 46:502-526.

Rao, Hayagreeva, Philippe Monin, and Rodolphe Durand. 2003. "Institutional Change in Toque Ville: Nouvelle Cuisine as an Identity Movement in French Gastronomy." *American Journal of Sociology* 108:795-843.

Reay, Trish and C. R. Hinings. 2009. "Managing the Rivalry of Competing Institutional Logics." *Organization Studies* 30:629-652.

Roberts, Peter W. 2008. "Charting Progress at the Nexus of Institutional Theory and Economics." Pp. 560-572 in *The SAGE Handbook of Organizational Institutionalism*, edited by R. Greenwood, C. Oliver, K. Sahlin, and R. Suddaby. Los Angeles, CA: SAGE.

Romer, Paul M. 1990. "Endogenous Technological Change." *Journal of Political Economy* 98:S71-S102.

Rosen, Sherwin. 1974. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 82:34-55.

Rosenberg, Nathan. 1976. *Perspectives on Technology*. New York: Cambridge University Press.

—. 1982. *Inside the Black Box: Technology and Economics*. New York: Cambridge University Press.

—. 2000. *Schumpeter and the Endogeneity of Technology: Some American Perspectives*. New York: Routledge.

Rothman, Hal K. 1998. *The Greening of a Nation?: Environmentalism in the United States Since 1945*. Belmont, CA: Wadsworth Publishing Co.

Ruef, Martin. 1999. "Social Ontology and the Dynamics of Organizational Forms: Creating Market Actors in the Healthcare Field, 1966-1994." *Social Forces* 77:1403-1432.

Sachs, Wolfgang. 1999. *Planet Dialectics: Explorations in Environment & Development*. New York: Zed Books.

—. (1984) 1992. *For Love of the Automobile: Looking Back into the History of our Desires*. Translated by D. Reneau. Berkeley and Los Angeles, CA: University of California Press.

Scherer, Frederic M. 1965. "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions." *American Economic Review* 55:1097-1125.

Schiffer, Michael Brian. 2001. "Toward an Anthropology of Technology." Pp. 1-15 in *Anthropological Perspectives on Technology*, edited by M. B. Schiffer. Dragoon, Arizona: An Amerind Foundation Publication.

Schneiberg, Marc and Tim Bartley. 2001. "Regulating American Industries: Markets, Politics, and the Institutional Determinants of Fire Insurance Regulation." *American Journal of Sociology* 107:101-146.

Schneiberg, Marc, Marissa King, and Thomas Smith. 2008. "Social Movements and Organizational Form: Cooperative Alternatives to Corporations in the American Insurance, Dairy, and Grain Industries." *American Sociological Review* 73:635-667.

Schneiberg, Marc and Sarah A. Soule. 2005. "Institutionalization as a Contested, Multilevel Process: The Case of Rate Regulation in American Fire Insurance." Pp. 122-160 in *Social Movements and Organization Theory*, edited by G. F. Davis, D. McAdam, W. R. Scott, and M. N. Zald. New York: Cambridge University Press.

Schumpeter, Joseph A. 1934. *The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*. Cambridge, MA: Harvard University Press.

Scott, W. Richard. 1995. *Institutions and Organizations*. Thousand Oaks, CA: SAGE.

—. 2001. *Institutions and Organizations*. Thousand Oaks, CA: SAGE.

—. 2008. *Institutions and Organizations*. Thousand Oaks, CA: SAGE.

Scott, W. Richard and John W. Meyer. 1983. "The Organization of Societal Sectors." Pp. 129-153 in *Organization Environments: Ritual and Rationality*, edited by J. W. Meyer and W. R. Scott. Beverly Hills, CA: SAGE.

Scott, W. Richard, Martin Ruef, Peter J. Mendel, and Carol A. Caronna. 2000. *Institutional Change and Healthcare Organizations : From Professional Dominance to Managed Care*. Chicago, IL: University of Chicago Press.

Seo, Myeong-Gu and W. E. Douglas Creed. 2002. "Institutional Contradictions, Praxis, and Institutional Change: A Dialectical Perspective." *Academy of Management Review* 27:222-247.

Sewell, William H., Jr. 1992. "A Theory of Structure: Duality, Agency, and Transformation." *American Journal of Sociology* 98:1-29.

Shrivastava, Paul. 1994. "The Evolution of Research on Technological Crises in the US." *Journal of Contingencies & Crisis Management* 2:10-20.

Sine, Wesley D., Heather A. Haveman, and Pamela S. Tolbert. 2005. "Risky Business? Entrepreneurship in the New Independent-Power Sector." *Administrative Science Quarterly* 50:200-232.

Sine, Wesley D. and Brandon H. Lee. 2009. "Tilting at Windmills? The Environmental Movement and the Emergence of the U.S. Wind Energy Sector." *Administrative Science Quarterly* 54:123-155.

Singh, Jitendra V., David J. Tucker, and Robert J. House. 1986. "Organizational Legitimacy and the Liability of Newness." *Administrative Science Quarterly* 31:171-193.

Snow, David A., E. Burke Rochford, Jr., Steven K. Worden, and Robert D. Benford. 1986. "Frame Alignment Processes, Micromobilization, and Movement Participation." *American Sociological Review* 51:464-481.

Strang, David and Sarah A. Soule. 1998. "Diffusion in Organizations and Social Movements: From Hybrid Corn to Poison Pills." *Annual Review of Sociology* 24:265-290.

Suarez, Fernando F. 2004. "Battles for Technological Dominance: An Integrative Framework." *Research Policy* 33:271-286.

Suchman, Mark C. 1995. "Managing Legitimacy: Strategic and Institutional Approaches." *Academy of Management Review* 20:571-610.

Suddaby, Roy and Royston Greenwood. 2005. "Rhetorical Strategies of Legitimacy." *Administrative Science Quarterly* 50:35-67.

Tarrow, Sydney G. 1998. *Power in Movement: Social Movements and Contentious Politics*. New York: Cambridge University Press.

Tassey, Gregory. 2000. "Standardization in Technology-based Markets." *Research Policy* 29:587-602.

Thompson, James D. 1967. *Organizations in Action: Social Science Bases of Administrative Theory*. New York: McGraw-Hill.

Thornton, Patricia H. 2002. "The Rise of the Corporation in a Craft Industry: Conflict and Conformity in Institutional Logics." *Academy of Management Journal* 45:81-101.

—. 2004. *Markets from Culture: Institutional Logics and Organizational Decisions in Higher Education Publishing*. Stanford, CA: Stanford University Press.

Thornton, Patricia H. and William Ocasio. 1999. "Institutional Logics and the Historical Contingency of Power in Organizations: Executive Succession in the Higher Education Publishing Industry, 1958-1990." *American Journal of Sociology* 105:801-844.

—. 2008. "Institutional Logics." Pp. 99-129 in *The SAGE Handbook of Organizational Institutionalism*, edited by R. Greenwood, C. Oliver, K. Sahlin, and R. Suddaby. Los Angeles, CA: SAGE.

Tilly, Charles. 1978. *From Mobilization to Revolution*. Reading, MA: Addison-Wesley Publishing Co.

Tolbert, Pamela S. and Lynne G. Zucker. 1983. "Institutional Sources of Change in the Formal Structure of Organizations: The Diffusion of Civil Service Reform, 1880-1935." *Administrative Science Quarterly* 28:22-39.

Tripsas, Mary. 1997. "Unraveling the Process of Creative Destruction: Complementary Assets and Incumbent Survival in the Typesetter Industry." *Strategic Management Journal* 18:119-142.

Tushman, Michael L. and Lori Rosenkopf. 1992. "Organizational Determinants of Technological Change: Towards a Sociology of Technological Evolution." *Research in Organizational Behavior* 14:311-347.

Unruh, Gregory C. 2002. "Escaping Carbon Lock-in." *Energy Policy* 30:317-325.

Van de Ven, Wynand P. M. M. and Bernard M. S. Van Praag. 1981. "The Demand for Deductibles in Private Health Insurance: A Probit Model with Sample Selection." *Journal of Econometrics* 17:229-252.

Von Burg, Urs. 2001. *The Triumph of Ethernet: Technological Communities and the Battle for the LAN Standard*. Stanford, CA: Stanford University Press.

Wade, James B., Joseph F. Porac, and Timothy G. Pollock. 1997. "Worth, Words, and the Justification of Executive Pay." *Journal of Organizational Behavior* 18:641-664.

Waguespack, David M. and Lee Fleming. 2009. "Scanning the Commons? Evidence on the Benefits to Startups Participating in Open Standards Development." *Management Science* 55:210-223.

Weber, Klaus, Kathryn L. Heinze, and Michaela DeSoucey. 2008. "Forage for Thought: Mobilizing Codes in the Movement for Grass-fed Meat and Dairy Products." *Administrative Science Quarterly* 53:529-567.

Weldon, Foster L. 1971. "Evolutionary Public Transportation: Some Implications for Propulsion Systems." Pp. 8-14 in *International Electric Vehicle Symposium*, vol. 2. Atlantic City, NJ: International Electric Vehicle Symposium.

Westphal, James D., Ranjay Gulati, and Stephen M. Shortell. 1997. "Customization or Conformity? An Institutional and Network Perspective on the Content and Consequences of TQM Adoption." *Administrative Science Quarterly* 42:366-394.

Wilde, Joachim. 2000. "Identification of Multiple Equation Probit Models with Endogenous Dummy Regressors." *Economics Letters* 69:309-312.

Woodward, Joan. 1965. *Industrial Organization: Theory and Practice*. London: Oxford University Press.

Wouk, Victor. 1971. "Electric Cars: The Battery Problem." *Science and Public Affairs: Bulletin of the Atomic Scientists* 27:19-22.

—. 1986. "Two Decades of 'High Performance' EV Fleet Experience." Pp. 82-97 in *International Electric Vehicle Symposium*, vol. 8. Washington DC: International Electric Vehicle Symposium.

Zelner, Bennet A., Witold J. Henisz, and Guy L. F. Holburn. 2009. "Contentious Implementation and Retrenchment in Neoliberal Policy Reform: The Global Electric Power Industry, 1989--2001." *Administrative Science Quarterly* 54:379-412.

Zietsma, Charlene and Thomas B. Lawrence. 2010. "Institutional Work in the Transformation of an Organizational Field: The Interplay of Boundary Work and Practice Work." *Administrative Science Quarterly* 55:189-221.

Zilber, Tammar B. 2002. "Institutionalization as an Interplay between Actions, Meanings, and Actors: The Case of a Rape Crisis Center in Israel." *Academy of*

Management Journal 45:234-254.

—. 2006. "The Work of the Symbolic in Institutional Processes: Translations of Rational Myths in Israeli High Tech." *Academy of Management Journal* 49:281-303.

—. 2007. "Stories and the Discursive Dynamics of Institutional Entrepreneurship: The Case of Israeli High-tech after the Bubble." *Organization Studies* 28:1035-1054.