# ALIGNING INSTITUTIONAL LOGICS TO ENHANCE REGIONAL CLUSTER EMERGENCE: EVIDENCE FROM THE WIND AND SOLAR ENERGY INDUSTRIES

by

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For over a century, researchers from diverse intellectual disciplines have tried to explain the emergence of regional business clusters. I contribute to research on cluster emergence by applying an institutional logics framework to model how cluster emergence is influenced by such factors as supportive institutional logics, knowledge spillover, labor pooling, and technological uncertainty. This study is guided by the research question: How do institutions, specifically, varying levels of a congruous institutional logic, affect regional cluster emergence?

Using the passage of the 1978 Public Utility Regulatory Policies Act (PURPA) as a catalyst for business cluster emergence in the renewable energy sector, this study examines the emergence of wind and solar energy manufacturing clusters. I test hypotheses about the positive influences of a congruous institutional logic across U.S.

metropolitan statistical areas to see if the relative prevalence of a congruous institutional logic results in more firms and greater levels of clustering. For example, a pro-environmental sentiment among human populations aligns, or in other words, is congruous, with renewable energy manufacturing. I use fixed effects estimation to test several hypotheses regarding positive direct and moderating effects of institutional alignment on cluster emergence. I find that congruous institutional logics have a positive direct influence on clustering, and as technological uncertainty increases, this positive direct influence is enhanced. I find only partial support for the moderating influence of congruous institutional logics on the positive direct effect of positive externalities on clustering. This study contributes to practice and theory by building a model and supporting hypotheses on the influence of institutional fit on regional cluster emergence.

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# CHAPTER I

# INTRODUCTION

The geographic area known as Silicon Valley, in the southern part of the San Francisco Bay Area, is widely recognized as a hub of high-tech business development and innovation. Silicon Valley is the third largest high-tech manufacturing center in the U.S., according to a 2008 survey, with 225,300 high-tech jobs and the largest high-tech manufacturing center in the U.S. The region has the highest concentration of high-tech workers of any metropolitan area and the highest average high-tech salary (AeA, 2008). Silicon Valley has become the archetypical example of a regional cluster (Saxenian, 1994).

A regional cluster is simply a group of interconnected companies and institutions doing business in a similar industry or organizational field in a particular geography (Porter, 1998a). Regional clusters can have profound economic impacts on their regions. Regional clusters create positive self-reinforcing feedback loops (Arthur, 1994) in the regional and national economy, resulting in potentially large economic growth within their geography. Additionally, the increasing economic returns that regional clusters deliver run contrary to predictions that globalization will negate locational advantages (Guillen, 2001; Marquis & Battilana, 2009, forthcoming). Researchers, economic developers, and politicians are thus extremely interested in understanding how and why regional clusters emerge.

Why do regional clusters develop? So far researchers know little about the natural seeding and growth of clusters (Noted exception: Chiles, Meyer & Hench, 2004). Trying to explain cluster emergence, Pouder and St. John (1996: 1198) state, "In some ways, clusters of firms are analogous to forests of trees. Although one cannot anticipate exactly when or where the first seed will land within a field, once the seed is implanted, it is highly likely more trees will follow." However, this view is overly deterministic. If it were true, regional clusters would be more common. We would expect to see software development clusters populating regions around Phoenix and Fargo, in addition to the well-established clusters in Seattle and the Bay Area.

Research shows that, in general, regional clusters exist because the locational advantages of a particular area are greater than the benefits of locating in a more dispersed pattern. These locational advantages include both access to natural resources and positive externalities, such as labor market pooling or the knowledge spillover that result from business clustering. However, the influence of natural resources on location choice is not as great as might be expected. In a recent study, natural resources explained only 20 percent of location selection (Ellison & Glaeser, 1999). Researchers studying the influence of externalities on regional clustering have considered firm benefits resulting from enhanced access to geographically bound factor markets, knowledge, and innovation (see Lawson, 1999; Newlands, 2003; Tallman, Jenkins, Henry & Pinch, 2004 for reviews). Surprisingly little research explores the advantages of geographically bound institutional contexts.

The enduring locational advantages to firms in regional clusters are rooted in resources and capabilities that are difficult or expensive to transfer (Barney, 1991; Wernerfelt, 1984). While globalization (the rapid growth of international trade and investment) makes factor markets and codified knowledge highly transferable, research has shown that regional clusters maintain their inimitability (Guillen, 2001). Although many resources and capabilities are transferable, geographical, institutional, and inter-organizational contexts are not. A complete explanation of the emergence and performance of regional clusters requires an understanding of the role played by such inimitable and non-transferable resources. I contribute to our understanding of the emergence and performance of regional clusters by exploring the role of one such resource: the institutional context. The research question—*How institutions, specifically, varying levels of a congruous institutional logic, affect regional cluster emergence*—guides this study. In order to clarify my research question, I next define institutions, congruous institutional logics, and regional clusters.

## Defining Institutions

Institutions are "multifaceted, durable social structures, made up of symbolic elements, social activities, and material resources" (Scott, 2001: 49). Institutions limit and define individuals' choice sets and as such influence social and economic activity. Many disciplines address the impact of institutions—forces within society, culture, and markets— that pressure organizations to behave and adopt forms that conform to these forces. The various disciplines create slightly different flavors of institutional theory (i.e.Meyer & Rowan, 1977; North, 1990), which Scott (2001) reviews and compares.

Scott (2001) integrated the various streams of institutional research into three pillars, or types, of institutional forces—regulative, normative, and cultural-cognitive. Regulative institutions are formalized rules in society or an organizational field that derive their force from legal systems. Normative institutions are based on value systems that derive their force from moral legitimacy. Cultural-cognitive institutions are agreed-upon definitions and beliefs that derive their force from cultural legitimacy.

These three types of institutions can operate at many different levels, ranging from an organizational subsystem to a world system (Scott, 2001). However, the most important level of analysis for researchers investigating institutional processes within institutional theory is the organizational field (DiMaggio & Powell, 1983; Scott, 2001). An organizational field is a group of organizations, which have a cognitive and social cohesiveness such that they "constitute a recognized area of organizational life" (DiMaggio & Powell, 1983). For example, U.S. museums (DiMaggio, 1991) or U.S. banks (Marquis & Lounsbury, 2007) can be considered organizational fields. Institutional fields differ from regional clusters because regional clusters are necessarily geographically bound and contain many organizations and inter-institutional systems. Thus, organizations focusing on a particular technological arena such as wind or solar power generation comprise an organizational field regardless of their geographic location. A regional cluster of solar energy manufacturers would be a subset of the organizational field, confined to a particular location. How the three pillars of institutional theory influence activities within an organizational field can be measured by institutional logics.

Institutional Logics

According to Thornton and Ocasio, 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. (Thorton & Ocasio, 1999: 804)

Friedland and Alford (1991) were the first theorists to introduce the concept of institutional logics to represent institutional belief systems that guide actions of organizations and actors. It is important to clarify that institutional logics have meaning *and* actions associated with them (Thornton & Ocasio, 2008). By including actions, institutional logics overcome the difficulty in measuring institutional influences on organizational activities. I define institutional logics that fit an individual or organizational belief system to be *congruous* institutional logics. Congruous means "being in agreement, harmony, or correspondence; conforming to the circumstances or requirements of a situation" (Merriam-Webster, 2009). As such, a congruous institutional logic can be thought of as being harmonious with a firm's activities.

For example, a common belief in the institutional logic of wealth protection in mutual fund management in Boston existed at the same time as an institutional logic of wealth growth in mutual fund management in New York City. These different institutional logics, which were congruous in each city, then in turn influenced what were deemed appropriate management behaviors in each city (Lounsbury, 2007). Lounsbury assumed the appropriate institutional logic was represented in each city, but did not measure how much of that congruous logic was represented in the city and how that level of a congruous logic influenced the amount of each type of money management firm.

This study measures the prevalence of a congruous institutional logic across many cities. And although Lounsbury was not studying regional clusters, his study reinforced how institutional logics can be associated with geographic regions, which are themselves associated with variance in institutions and institutional logics (Thornton & Ocasio, 2008). And yet geographic regions are not the same as regional clusters. Next, I clarify the definition of regional clusters used in this study.

## Defining Regional Clusters

Researchers examine regional clusters from several schools of thought, including theories of agglomeration, knowledge, untraded interdependencies, and evolutionary economics. (A review of the theories employed is in Appendix A.) There is overlap between the definitions of many of the terms used by these schools of thought to identify regional clusters. They include the terms agglomeration economies, industrial districts, industrial regions, competency regions, and communities. Despite the definitional variances, together their propositions build toward a more complete model of regional clusters from which to begin this study than any one school alone. A theme common to all of these terms is the notion of interrelated industries bound by a geographic region. For this study, I use Porter's recent and encompassing definition:

> A cluster is a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities. (1998a, p.: 199)

This study examines the phenomenon of regional clusters. Population ecology and network studies address similar phenomena. However, as I explain below, the definition I adopt for regional clusters leads me to exclude most research based on the theory of population ecology, but I do include the body of work inclusive of geographically bound network research.

Population ecology measures organizational performance in relation to foundings, density, and demise of homogenous organizations (Carroll & Hannan, 2000). A population of organizations can be in a geographically bound regional cluster, but a population of one organizational form or industry is not sufficient to comprise a cluster on its own. For example, population ecology has studied the performance implications of hotels based on hotel size and density (Baum & Ingram, 1998), and yet this does not represent a tourism cluster. Additionally, population ecology treats all organizations within a population as equal, resulting in contradictory implications (Freeman, Audia, Cook & Massey, 2006). Regional clusters are comprised of multiple homogenous industries or heterogeneous organizational populations within geographic boundaries. Clearly, a true representation of a regional cluster in a study cannot track a population of one organizational form. Since this study focuses on regional clusters, it does not draw from population ecology research.

Regional cluster research overlaps with network research. Explanations of the emergence and performance of regional clusters must consider the implications of geographically bound networks, such as biotechnology firms in Boston (Owen-Smith & Powell, 2004). However, regional clusters and networks are not synonymous. Regional clusters are geographically bound interrelated industries, which are not the same as networks considering, "network research investigates relational processes and structures at many different levels of analysis" (Kilduff & Tsai, 2003, p.: 4). Network research focuses on the structure of relational ties between nodes, without geographic or level of analysis assumptions. Although networks need not be bound by a geographic region, they are often more cohesive with propinquity. Physically proximate networks are more effective at transmitting information. For example, researchers have shown venture capital funds prefer to invest in biotechnology ventures that are geographically nearby (Powell, Koput, Bowie & Smith-Doerr, 2002).

However, although networks are an important structural component of clusters, network effects are distinguishably different from those of clusters. Geoffrey Bell (2005) modeled the effects of management networks, firm networks, and cluster membership on innovation, finding that although both manager networks and cluster membership positively and significantly affected innovation, cluster membership had a much greater effect than manager networks. This study draws from only that network research that is relevant to geographically proximate interrelated organizations and associated institutions.

The remainder of this dissertation is organized as follows. In the following chapter, Chapter 2, I systematically review previous work related to the institutional and geographic contexts of cluster emergence, drawing on Scitovsky's (1957) two concepts of external economies. As noted above, cluster research emphasizes benefits derived from positive externalities. Using Scitovsky's two external economies, I organize previous research according to the type of beneficial externalities it explains. I begin by explaining Scitovsky's concepts of pecuniary and technological external economies, and then examine previous empirical research through this lens, highlighting findings that show how institutions interact with these externalities. I then review institutional logics in order to show how it can be used to bridge the gaps in the reviewed regional cluster research.

In Chapter 3, I use the institutional logics framework to develop a model and hypotheses. The institutional logics perspective is appropriate because it instantiates institutions through meaning *and* action (Thornton & Ocasio, 2008) to explain how institutions influence actions of people and organizations (Friedland & Alford, 1991). I develop three hypotheses to test the influence of congruous institutional logics across geographic areas to see if the relative prevalence of a congruous institutional logic results in more firms and greater levels of clustering.

In Chapters 4 and 5, I describe the methods I employed to test the hypotheses and the results of the analysis, respectively. For the empirical setting, I consider the passage of the 1978 Public Utility Regulatory Policies Act (PURPA) a catalyst for business cluster emergence in the renewable energy sector and examine the emergence of wind and solar energy clusters after the passage of this act. I use fixed effects estimation on the panel data set to test several hypotheses regarding positive direct and moderating effects of institutional alignment on cluster emergence and growth. I find that congruous institutional logics have a positive direct influence on clustering, and as technological uncertainty increases, this positive direct influence is enhanced. I find only partial support for the moderating influence of congruous institutional logics on the positive direct effect of positive externalities on clustering.

Chapter 6 provides conclusions and implications of this study. By examining the theoretical, public policy, and managerial implications of the results, this study contributes to our understanding of the emergence and performance of regional clusters.

The findings of this study show institutional contexts do influence clustering behavior of firms. As such, this study contributes to a more thorough understanding of the emergence of regional clusters.

# CHAPTER II

# LITERATURE REVIEW

[1]Existing empirical research on clusters has shown benefits resulting from positive externalities generated in regional clusters. While researchers have conjectured about the importance of institutional contexts, to date, we know little empirically about how it influences cluster emergence. To streamline and elucidate prior research, I organize this review of the empirical literature through the lens of Scitovsky's (1957) two external economies. Following the review of the empirical research on clusters, I present a review of institutional logics as a theoretical bridge to fill the gap in cluster research on institutional influences.

## Scitovsky's Two External Economies

Externalities are third-party benefits or detriments resulting from market transactions between buyers and sellers (Mikesell, 2003). They are considered third-party benefits or detriments because they do not accrue to the decision maker. A common example of externalities, such as a neighboring factory polluting the air, tends to

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[1] Varying disciplines and intellectual genealogies shape researchers' approaches to studying regional clusters. Because of these differing origins, researchers tend to come from at least four different schools of thought regarding the sources of advantages to businesses in clusters. A review of the differing schools of thought applied to regional clusters is located in Appendix A.

emphasize the negative outcomes from externalities. However, in the case of regional clusters, externalities are often positive.

Regional clusters create a positive feedback loop (Arthur, 1994) where the concentration of interrelated firms creates benefits, which encourages more firms to form or locate in the region, which creates more benefits, and so forth. Of course, the impact of more firms clustering may reach an inflection point where congestion results in a detriment (Folta, Cooper & Baik, 2006). However, benefits outweigh detriments during the process of cluster growth and emergence. In other words, the externalities are summatively positive. Most of the empirical research on clusters highlights the positive nature of externalities.

Tibor Scitovsky (1957) delineated two types of external economies (a.k.a. externalities), in order to improve the application of the concept of externalities to economic theory: pecuniary and technological. The first external economy is pecuniary. Pecuniary externalities exist where,

> the *profits* of the firm depend not only on its own output and factor inputs but also on the output and factor inputs of other firms" (Scitovsky, 1954: 146, emphasis in original).

The second external economy is technological. Technological externalities exist whenever,

> the *output* of a firm depends not only on the factors of production utilized by this firm but also on the output and factor utilization of another firm or group of firms. (Scitovsky, 1957:145, italics added).

Scitovsky conceives of pecuniary externalities as broader and more encompassing than technological externalities, because in addition to non-market interdependence between producers, pecuniary externalities include market-based interdependence between producers. Scitovsky gives an example of a pecuniary externality as the situation when "investment in industry A will cheapen its product; and if this is used as a factor in industry B, the latter's profits will rise." (Scitovsky, 1957: 146) He distinguishes pecuniary externalities from the creation of a proper consumers' surplus, since it is benefiting firms rather than consumers. In order to clarify the meaning of pecuniary externalities, it helps to remember the definition of pecuniary as relating to or measured by money. Therefore, pecuniary externalities are third-party benefits improving a firm's profits. Pecuniary externalities emphasize increased profits because of market benefits such as reduced costs of inputs or increased demand for outputs. An example of a positive pecuniary externality in clusters is a lower wage for skilled labor, because workers know there is employment for their particular skills in the cluster's geographic region.

Technological externalities are more specific in definition than pecuniary externalities because the technological externality does not include market-based interdependence between producers. For example, a well-known story of a positive technological externality comes from the symbiotic relationship between bees and flowers. Orchard owners' benefit from pollination of their fruit trees while beekeepers are producing honey for their own profit. Orchard owners and beekeepers mutually benefit even though there may not be direct contracts or market mechanisms. Although this is similar to an economy of scope, where a by-product of production may result in cost-savings in another location or product, economies of scope usually occur within the same firm whereas technological externalities do not.

Scitovsky felt this type of positive externality was rather rare. However, in 1957, the implications of a knowledge-versus-industrial economy had not been explored. In a knowledge-based economy, learning and knowledge spillover are very important examples of technological externalities. In order to clarify the meaning of technological externalities, it is helpful to consider the definition of technological as improving the completion of a task (Scitovsky, 1957). Technological externalities thus are third-party benefits that improve a firm's production capabilities or an individual's utility.

Knowledge spillover is the most common type of technological externality in business clusters (Fujita & Thisse, 1996). Scitovsky did not foresee the supplanting of an industrial economy with a knowledge economy, and thus did not realize the potential prevalence and importance of technological externalities. Technological externalities became more prevalent and studied as the knowledge revolution supplanted the industrial revolution as a driving force in economic growth (Rifkin, 2000). Researchers began focusing on advantages of clustered organizations in knowledge creation, innovation, and dissemination. Researchers such as Pouder and St. John and Powell and colleagues (Pouder & St. John, 1996; Powell, Koput & Smith-Doerr, 1996) highlighted the importance of clustered organizations' interactions and embeddedness in generating knowledge.

Focusing on positive externalities to understand positive feed back loops (Arthur, 1994) fueling cluster emergence provides a systematic framework for examining institutional influences on cluster emergence. Doeringer and Terkla (1995) emphasize the need to understand positive externalities to understand the clustering process. Despite the seemingly obvious interaction between positive externalities and institutional contexts on regional clusters, the interaction is under-studied. Table 1 summarizes the two types of externalities.

**Table 1.** Two External Economies in Regional Cluster Research

| Externality | Mechanism | Benefit |
|---|---|---|
| Pecuniary | Non-market and market based | Improved profits |
| Technological | Non-market based | Improved production function or individual utility (also leading to improved profits) |

Beneficial pecuniary and technological externalities drive positive feedback loops fueling regional cluster emergence, thus providing a salient lens for analyzing previous research. Scitovsky's lens aids in assimilating findings and gaps, indicating valuable areas for future research. This literature review assimilates findings, institutional influences, and methodology employed in prior research for each type of externality. I first discuss positive externalities, then discuss negative externalities of each type, and then how previous research has examined institutional influences.

## Pecuniary Externalities and Clusters

Researchers focusing on pecuniary externalities in regional clusters have found many benefits for clustered firms, including enhanced access to existing resources and reduced costs of inputs, increased legitimacy, and access to specialized inputs. These benefits derive from location near necessary resources or markets, increased access to inputs, shared services, or increased competition. Negative externalities include increased competition for resources and derive from congestion. Institutional influences are reviewed with respect to each of the three institutional pillars—regulatory, normative, and cultural-cognitive (Scott, 2001). Researchers use a variety of methods to study institutional influences, such as event history analysis and qualitative research. This section concludes with a summary of the research on clusters and pecuniary externalities. First I review previous findings on pecuniary externalities for clustered firms.

## Findings from Prior Research on Pecuniary Externalities

**Enhanced access to existing resources.** Empirical research on clustering demonstrates that access to existing resources (Audretsch & Feldman, 2004; Decarolis & Deeds, 1999; Karagozoglu & Lindell, 1998) increases with increasing concentration of firms (Bresnahan, Gambardella & Saxenian, 2001) and reduces costs of inputs. For example, Lorenzoni and Lipparini (1999) found network stability and economic and social interactions reduced transaction costs in the packaging manufacturing industry. A review of the last 10 years of economic geography research (Rosenthal & Strange, 2007) found that clustered firms have better access to labor market pooling, industrial inputs, natural advantages, and increased consumption, and that they gain home market advantages, and improved rent seeking.

**Legitimacy.** Normative and cognitive legitimacy (Scott, 2001) enhances survival because organizations need resources, and legitimacy helps attract resources. Clusters, or other geographically bounded regions, enhance the ability to acquire resources and legitimacy because both are easier to acquire with propinquity. For example, McKendrick, Jaffee, Carroll, and Khessina (2003) found that legitimacy through identity formation of disk array producers was enhanced by geographical agglomeration. Studying entrepreneurship in alternative energy foundings in New York and California, Sine, Haveman, and Tolbert (2005) showed that legitimacy reduced the perceived risk of using new technology, thus increasing new business foundings.

**Access to specialized inputs.** Other advantages to regional clusters found in the management literature include resources with indivisibilities, such as when a regional cluster has critical mass to support specialized law or investment firms. Saxenian (1990), in her study of Route 128 and Silicon Valley, found that clustered firms benefited from specialized business functions present within regional clusters. Saxenian (1990) emphasizes the importance of Stanford University, trade associations, and other for-profit organizations that provide services that firms cannot afford individually. A study of two European ceramic tile clusters by Hervas-Oliver and Albors-Garrigos (2007) supports this finding. Additionally, Stuart and Sorenson (2003) illustrated the importance of public research universities and the availability of venture funding, in granting entrepreneurs access to resources, in order to found new firms.

**Negative externalities.** Not all externalities are beneficial or equally distributed. Detriments of clustering tend to come from problems with congestion. In their study on internationalization of information technology firms, Fernhaber and colleagues (2007) found that access to resources promoting internationalization were positive until cluster size reached an inflection point, after which access to resources decreased. Similarly, as clusters grow, firms benefit from improved access to alliance partners and private equity partners until cluster size reaches an inflection point where benefits begin to decline (Bresnahan et al., 2001). Besides negative externalities, distribution of positive externalities can be heterogeneous within a cluster. For example, in cellular handset manufacturing clusters, collocating is more beneficial to less capable firms (Alcacer, 2006). Locating in a cluster is not always optimal, and consideration should be given to firm capabilities and cluster characteristics. Despite these negative externalities, positive pecuniary externalities dominate cluster research. Next, I examine research at the nexus of pecuniary externalities, institutions, and clusters.

## Institutions and Pecuniary Externalities

In this section, I show how previous research has found that each of the three types of institutions influence pecuniary externalities. Regulatory institutions provide opportunities to increase prices paid for outputs or improved access to necessary inputs such as skilled labor. Normative institutions have less research than the other two, but can encourage support for philanthropy that could help develop sources for inputs or increase demand for outputs. Cultural-cognitive institutions can increase clustering through institutional grooming of organizations or reduced transaction costs.

**Regulatory institutions.** Regulatory institutions influence pecuniary externalities by influencing the cost of inputs or market demand. Specific to pecuniary externalities, regulatory institutions benefit clustered firms through mechanisms such as reducing the cost of inputs or increasing the demand for outputs. By improving the business climate for firms, regulatory institutions can thus increase clustering of firms. Fromhold-Eisbeth and Fromhold (2005) point out that although researchers have identified institutions as important assets to clusters, there has been insufficient study and we lack a complete understanding of how institutions affect cluster formation.

Local interpretations of existing regulations or flexibility in creating regulations influences cluster development. Political decentralization, where local governments have more flexibility in developing regulations, creates opportunities to encourage the development of clusters (Benton, 1992; Ganne, 1995; Trigilia, 1992). Zeitlin (1995) argues that the absence of flexibility for local governments with regulatory controls stultifies regional cluster development, because local governments are prevented from investing in infrastructure, training, or other business incentives.

Similarly, although not specifically studying clusters, literature on regulatory influences on other geographically constrained entities has implications for geographically constrained clusters. States and state regulations are examples of formal institutions affecting pecuniary externalities. Ingram and Simons (2000) found a stabilizing effect from state formation that resulted in an increase in new firm foundings. In studies of alternative energy foundings, when regulations (under PURPA) lowered economic entry barriers, foundings increased for those using new technology (Russo, 2001, 2003; Sine, Haveman & Tolbert, 2005). Russo (2001) found that the nature of the regulatory environment and institutions affected alternative energy and cogeneration facility foundings, such that clear statement of avoided cost calculations by state regulators and the existence of trade associations increased foundings. Just as Russo (2001) found that utilities sought to have PURPA interpreted to their benefit, Wade, Swaminathan, and Saxon (1998) found that powerful organizations, such as the Women's Christian Temperance Union during prohibition, will seek to shape institutional change to their benefit, drastically affecting the viability of the climate for firm foundings and potential for clustering.

In additional research on U.S. state-level regulatory institutions, Lee & Sine (2005) studied social movements in California and New Jersey. Their findings show that social movements, indicated by increasing Sierra Club membership, resulted in changes to the regulatory environment, which in turn resulted in increasing avoided cost rates. In a follow-up study, (Sine & Lee, 2009) the authors found popular support for environmental issues, as measured by Sierra Club membership, leads to more state regulatory policies for renewable energy, and the number of state regulatory policies leads to entrepreneurial opportunity recognition for wind energy projects. In a very interesting result, they found, contrary to the predictions of population ecology, that organizational density did not affect entrepreneurial activity once natural resources and environmental groups were in the model. Their findings suggest researchers should consider "how pre-existing regional differences in non-economic sectors can shape economic outcomes." (Lee & Sine, 2005: 114) My study seeks to test how institutions, as a non-economic sector, can influence cluster emergence.

**Normative institutions.** Normative institutions have not been a focus of cluster research because they are more about obligations and expected behaviors that influence human behaviors more than firm performance. Normative institutions bring the "prescriptive, evaluative and obligatory dimension into social life" (Scott, 2001: 54). However, research based on communities by Marquis and colleagues (Marquis, 2003; Marquis & Battilana, 2009, forthcoming; Marquis, Glynn & Davis, 2007), considers normative behaviors. Although they are researching unique norms that develop in communities—not clusters—their research can help understand potential normative influences on pecuniary externalities. For example, the norm that developed for corporate giving to the arts in Minneapolis, Minnesota, (Marquis et al., 2007) could generate access to specialized inputs. Researching the differences between corporate philanthropy in Columbus and Cleveland, Ohio, (Marquis et al., 2007), they found corporate philanthropy in Columbus focused on non-profits that benefit children, while corporate philanthropy in Cleveland focused on affordable housing. A norm supporting corporate philanthropy to support affordable housing could eventually lead to greater access to a labor pool. This type of research has not been tied to clusters, most likely because it is very difficult to link norm-driven behavior to reduced cost of inputs.

**Cultural-cognitive institutions.** Cultural cognitive institutions are agreed-upon definitions and beliefs that derive their force from cultural legitimacy. This drives what is considered to be appropriate behavior by individuals or organizations in support of identity (Scott, 2001). As stated by Fromhold-Eisbith and Eisbith (2005), there has been too little research on how associated informal institutions, such as norms and cultures of interaction, influence cluster formation.

In a fascinating study about the emergence of a musical theater cluster, Chiles and colleagues (2004) found that the important stabilizing and grooming nature of the local culture and institutions created 'wholesome' theater offerings that built upon previous successes leading to a positive feedback loop. Institutions such as local government, chambers of commerce, and the local culture encouraged more 'wholesome' theater offerings, which increased demand. The importance of understanding institutions for cluster survival is reinforced by Tan's (2006) study of the state-fostered Beijing science park that is experiencing premature ossification. Tan conjectures that the premature ossification is due to a mismatch between the institutional environment and the firms.

Ingram and Simons (2000), while not studying a regional cluster, are two of the few researchers to look at the interaction of the ideologies of organizations. They studied the implications of mutualism in ideologies on firm foundings of worker cooperatives in Israel. Interestingly, they found that increases in the population of credit cooperatives, which share ideology with worker cooperatives, increased worker cooperative foundings. They conjecture that the increase in firm foundings results from reduced transaction costs from benefits such as credible commitments and collective action. Since Ingram and Simons conceive that the alignment of ideologies reduces transaction costs, as a market-based transaction, this is an example of a pecuniary externality.

Carroll and Swaminathan (2000) found that authentic connection to the local regional identity increased new firm founding rates. In addition, when microbreweries and brewpubs aligned in their form-based identities they enhanced each other's legitimacy. By aligning with the local identity and with the form-based identity, microbreweries conformed to the agreed-upon definitions and beliefs for cultural legitimacy. This finding is supported by Freeman and Audia (2006) who state, "Similarities in resources have competitive effects on organizations, whereas similarities in cultural and ideological symbols appear to have mutualistic effects." (:152). Surprisingly, no one has studied mutualistic effects in regional clusters.

Although not specifically applied to regional clusters, demographic shifts affect regional institutions. Haveman and Rao (1997), studying the early California thrift industry, saw that the co-evolution of organizations and institutions changes as result of demographic shifts and the spread of Progressivism. The battle between the different types of thrifts represented the struggle between differing concepts of institutional logics.

The authors define institutional logics as the norms, rules, and ways of thinking, which comprise moral sentiments. Institutional logics provide an opportunity to study institutional influences on clusters. I review institutional logics after reviewing technological externalities research.

**Methodology for Pecuniary Externalities Research**

The type of analysis used in these studies is usually logit or event history analysis with the exception of Bresnahan and colleagues (2001) and Chiles and colleagues (2004), who qualitatively studied emerging clusters. Measures of firm-level success were founding, age, size of initial public offering, and alliances in biotechnology. Three studies examined cluster level performance as well, looking at number and size of firms, growth in sales, and return on assets (Bresnahan et al., 2001; Hervas-Oliver & Albors-Garrigos, 2007; Tan, 2006). Research settings varied considerably, with U.S. biotechnology and information technology being popular, but with other subjects represented as well, such as European manufacturers of cellular handsets, packaging equipment, and ceramic tiles.

One limitation common to some of these studies is how the researchers identify clusters. For example, one study identified a cluster if more than one division that produced cellular handset phones was located within 100 miles of another (Alcacer, 2006). In some studies, researchers identified clusters by generally accepted consensus in public or industry perception. Most of the studies are careful to not sample on a dependent variable of already being in a cluster (Exception: Bresnahan et al., 2001; Chiles et al., 2004). There are two notable exceptions: Fernhaber and colleagues (2007) calculated clusters based on firm density after accounting for all new information technology ventures across the U.S, and Russo (2003) calculated density of project filings for each county in California.

The empirical research in economic geography tends to focus on only one industry, rather than the generally accepted definition of clusters as being comprised of interrelated industries. For example, economic geography research rarely includes the presence of public research organizations in their studies. It is difficult to conclude that economic geography has adequately measured clusters in previous research.

In order to bring in relevant research on institutions, some of the literature reviewed did not study clusters (Carroll & Swaminathan, 2000; Haveman & Rao, 1997; Lee & Sine, 2005; Russo, 2001; Sine et al., 2005). However, since more than one organizational form or industry is necessary for regional clusters, these studies sample from more than one organizational form or industry. For example, Lee and Sine (2005) modeled how changing Sierra Club membership and regulations avoided costs for wind energy projects. They showed how cultural-cognitive institutions lead to regulatory institutions, which lead to more qualifying facility projects at the state level.

**Summarizing Pecuniary Externality Research**

Clearly, pecuniary externalities provide benefits to clustered firms. Some researchers found points of diminishing returns to cluster size, however all of those researchers studied only one type of organizational form or industry. Although negative externalities are expected from competition and congestion, without incorporating institutional environments or other organizations it is difficult to understand the systematic influence on cluster size. Overall, it appears that institutional environments are neglected in understanding transactional efficiencies from pecuniary externalities in clusters. Only one study (Stuart & Sorenson, 2003a) explained collocation in biotechnology resulting from proximity to venture capital necessary for entrepreneurial resource acquisition. Although not studying clusters, Ingram and Simons (2000) theorized institutional factors reduce transaction costs. They did not use organizations in the workers cooperatives' supply chain as would be expected, instead using financial institutions with similar ideology. This method could be applied to understand the influence of cultural-cognitive institutions on regional clusters.

Next, the literature review assimilates the previous research on technological externalities. Research focusing on knowledge spillover, learning, and innovation assumes much of the benefits from pecuniary externalities while highlighting benefits from technological externalities.

## Technological Externalities and Clusters

Researchers focusing on technological externalities have found many benefits for clustered firms, including knowledge spillover, and innovation, and knowledge created within networks and from social resources such as experience. These benefits derive from location near sources of the underlying knowledge and interaction with other firms. Negative externalities include unintended knowledge spillover derived from interactions with other firms. Institutional influences are reviewed with respect to each of the three institutional pillars—regulatory, normative, and cultural-cognitive (Scott, 2001). Researchers use a variety of methods including event history analysis and qualitative research. This section concludes with a summary of the research on clusters and technological externalities. First, I review previous findings on technological externalities for clustered firms.

## Findings from Prior Research on Technological Externalities

**Knowledge spillover.** Knowledge spillover increases production function, and thus is a technological externality. Research in this area emerged in the early 1990s, led by Jaffe, Trajtenberg, and Henderson's (1993) influential article. They found that the spread of ideas is greatly influenced by geographic proximity. Using forward citation patterns, they determined that patents are five to 10 times more likely to come from the same Metropolitan Statistical Area. Almeida and Kogut (1999) reinforced this by proving that knowledge spillovers are geographically limited.

Empirical research on technological externalities has shown that knowledge spillover increases with location and proximity (Rosenthal & Strange, 2007). One of the reasons is due to the geographically bound nature of the labor force. Almeida and Kogut (1999) tracked highly cited patents and the mobility of semiconductor engineers between firms, and found that knowledge flow is regionally constrained, and also that flow is partially due to the mobility of engineers. Zucker, Darby, and Brewer (1986) found that the emergence of the U.S. biotechnology industry was due to the basic scientific findings of university research scientists whose knowledge spilled over into their region. There is a feedback effect: when one biotechnology firm has already started operating in a ZIP code near a public research organization, then more are likely to form (Stuart & Sorenson, 2003a).

Another reason for knowledge spillover is local networks. Owen-Smith and Powell (2004) posit that formal linkages result from informal social interactions in the Boston biotech community. The differences between bottom-up cluster formation and top-down cluster fostering highlights the importance of embeddedness to cluster emergence. Although public policy makers try to encourage knowledge spillovers, publicly fostered clusters are less interconnected and create less innovation than organically developed clusters (Fromhold-Eisebith & Eisebith, 2005). The investment to foster clusters is wasted if the economic players are already networked (Newlands, 2003) or the area lacks an intellectual pole (Lawson & Lorenz, 1999) for developing the underlying science.

However, benefits come not only from network connections but also from value of the knowledge inherent in the network itself (Kogut, 2000). In their study of production networks, Lorenzoni and Lipparini (1999) found that clustering enhanced development of specialized knowledge internal and between firms.

**Innovation.** Studying innovation in Silicon Valley, Saxenian (1990) found the greater number of smaller businesses, in addition to mingling from shared business services and residential communities, results in more innovation and new business creation than in Boston's Route 128 area. Moody and White's (2003) findings that network cohesiveness results in more net benefit than network centrality supports this idea. Testing Saxenian's conception of Silicon Valley's culture, two economic geography articles measure the impact of adding employment to smaller firms, which they theorized as being more open to knowledge spillover than larger firms. Increases in employment to smaller firms in clusters (Henderson, 2003) resulted in more new business foundings, and in more productivity (Rosenthal & Strange, 2003). Owen-Smith and Powell (2004) showed how the influence of public research organizations in capturing value in a biotechnology cluster changed over time. Early in Boston's biotechnology cluster public research organizations were dominant, positively enhancing patents for firms in the region at the same time network centrality was negatively correlated to patents. Later when commercial organizations dominated the cluster, network centrality was positively correlated with increased patents.

**Evolving routines.** Other technological externalities for clustered firms result from evolving routines, which, as explained by evolutionary economics, provide a mechanism to understand cluster growth. Klepper (2007) showed how the U.S. auto industry cluster in Detroit emerged as new firms spun off from successful firms. He argued that the cluster could be explained through spin-offs alone and was not due to agglomeration economies. His evidence is strong enough to support the statement that spin-offs locate near parent firms as a mechanism of cluster growth, but is not as strong in his attempt at invalidating agglomeration economy benefits. Klepper's findings were moderated by Boschma and Wenting's (2007) study of the British auto industry, which showed agglomeration economies resulting from related industries. Operationalized as labor pool data, these related industries were necessary for starting a cluster. Once the cluster was initiated, their findings agreed that spin-offs were the main driver for cluster growth.

**Social learning.** Other advantages such as trust, understandings, and experience come from social resources developed from embeddedness. Uzzi (1997) found in his study of garment manufacturing that embeddedness resulted in trust which resulted in economies of time. Trust developed from a heuristic method of extra effort given between exchange partners acting in each other's interest. Saxenian (1994) found that a network of professional and social ties enhanced diffusion of knowledge, capabilities, and understandings, in a comparative case study of Silicon Valley and Route 128. Silicon Valley was the more successful location because of the understandings developed through social networks, collective learning, and collaborative relationships. Klepper (2005) found that television manufacturers were more successful when they developed experience in radio manufacturing. Boschma and Wenting (2007) found that clusters form where there are industries that are related, so that entrepreneurs gain experience prior to starting new ventures. Automobile manufacturing entrepreneurs were more successful than other auto manufacturers if they first gained experience in bicycle manufacturing.

**Negative externalities.** Not all effects from clustering are equally beneficial. Clustering can lead to unintended knowledge spillover. Yoffie (1993) found that semiconductor firms concerned about sharing technology avoided collocating with competitors. For the same reason, Chung and Alcacer (2002) found that foreign firms locating in the U.S. who were technologically advanced chose to avoid existing industry clusters. Studying the uneven distribution of externalities in clusters, Boschma and Ter wal (2007) found unequal innovation performance in clustered firms, such that more innovative firms had more out-of-cluster relationships. However, the direction of the causation in that finding is unclear. More innovative firms may attract more extra-local relationships. In an example of uneven distribution of externalities, Becchitti and Rossi (2000) found that smaller firms benefited more from shared knowledge about exporting.

And Audretsch and Feldman (1984) found that clustered firms performed better at the beginning of a cluster's life cycle and worse than non-clustered firms at the end of a cluster's life cycle. Despite these negative externalities, positive externalities dominate cluster research. However, a researcher must consider firm and cluster age when modeling externalities if it is a well-established industry or cluster. Next, I examine research at the nexus of technological externalities, institutions, and clusters.

## Institutions and Technological Externalities

In this section I describe how previous research has found the influence of each of the three types of institutions on technological externalities. Regulatory institutions can create environments that facilitate knowledge spillover by not enforcing non-compete clauses. Normative institutions have less research than the other two, but can encourage support for businesses connected through family networks. Cultural-cognitive institutions can increase knowledge spillover through accepted behaviors that encourage knowledge sharing or entrepreneurial endeavors.

**Regulatory institutions.** Theoretically, Pouder and St. John (1996) argue that 'hot spots' have institutional forces, which increase innovation. However, as the institutions ossify, they suppress innovation. In support of this idea, Maskell (2001) argued for the importance of the fit between institutions and industry in their ability to develop knowledge. In both articles, the authors do not differentiate between types of institutional fit.

Although it is clearly apparent that regulatory institutions such as laws, industry subsidies, and tax breaks should greatly influence technological externalities, I found a surprisingly small amount of recent empirical research with two exceptions. Russo (2003) modeled technological externalities in his study of wind energy filings in California. Although he considered the pecuniary externalities of efficient access to social capital and natural land resources where wind is abundant, he also considered the externality of access to knowledge embedded in counties with previous wind projects. More foundings and subsequent knowledge spillover resulted in conjunction with natural resources, social capital, and economic viability brought about by regulatory changes. Although not studying clusters, Stuart and Sorenson (2003b) found that spin-offs were more likely in California, where the institutional norm is to not enforce non-compete clauses. Where compete clauses are enforced, knowledge spillover is reduced.

**Normative institutions.** Normative institutions have not been studied much in cluster research. With the exception of the extended familial network in Italy (Piore & Sabel, 1984) where familial obligations to support each others' businesses facilitated the growth of clusters. These familial connections lead to knowledge spillover and increased innovation. Cultural-cognitive institutions have stronger support in previous research for enhancing technological externalities.

**Cultural-cognitive institutions.** Seminal research by Saxenian (1994) in her comparison of Route 128 and Silicon Valley determined that culture and institutions matter in firm performance. Silicon Valley was the more successful location because it had more mixing of work and residential venues and more shared institutions, which resulted in more opportunities for entrepreneurs. Romanelli and Khessina (2005) argue for a regional industrial identity, where people, both residents and external audiences, start businesses that match a strong regional industrial identity. In building their argument, they assume that Metropolitan Statistical Areas have one industry or organizational form, creating a strong signal for an existing cluster. This assumption does not align with the definition of cluster as interrelated industries and organizations. However, the idea of a regional identity attracting firms does support mechanisms of cluster growth.

In their study of the emergence of a cluster of musical theaters in Branson, Missouri, Chiles and colleagues (2004) found that cultural cognitive institutions reinforcing 'wholesomeness' provided stability throughout the evolution of the collective, as entrepreneurs creatively recombined resources that led to a positive feedback loop. In a rare study to look at initial foundings within populations, Audia and colleagues (2006) showed the importance of incorporating other industries in models. Initial foundings of instrument manufacturers are more likely with higher densities of competitive and synergistic firms. They argue that this is fueled by knowledge, not agglomeration economies, because instrument manufacturing has minimal shipping costs. However, they neglected to explain how initial foundings may be related to institutions in these areas.

## Methodology for Technological Externalities Research

For the reviewed studies, the type of analysis is usually logit or event history analysis. The dependent variable is most often firm founding, or a derivative such as age or death. The dependent variable has higher levels of detail for biotechnology, including information on alliances, funding, patents, and co-authors. The approach to sampling usually includes the entire U.S. There is concern about how some studies determine clusters, although in this grouping of empirical research there are excellent examples for determining clusters. For example, Becchetti and Rossi (2000) used not one, but two methods to calculate clusters: the Del Cole distance to calculated poles; and the Sforzi index, a ratio of employment in small and medium sized enterprises to national employment average in all size firms. In another example, Audia, Freeman, and Reynolds (2006) measured clustering within Labor Market Areas. This approach fails in rural areas because it covers geographic areas until a minimum population of 100,000 is reached. For rural areas, the geographic space required to accumulate 100,000 people can be quite large. The study included places like Kalispell, Montana, where the entire state has a population of 800,000 people. Sorenson and Audia (2000) used density of clumping by state. Almeida and Kogut (1999) did not sample on the dependent variable of being in a pre-identified cluster, but rather used data on the entire industry and identified clusters by closely located firms. However, they made Oregon and Washington one region, which is a geographically huge area with dubious informative value for clusters.

The unit of analysis for most of these articles was foundings and exits. Most researchers aggregated data to the state level with the exceptions of Russo (2003), who aggregated to the county level; Klepper (2007), who aggregated to the metropolitan statistical area level; and Owen-Smith and Powell (2004), who analyzed at the firm and network level in Boston. The greatest limitation in the methodology is that institutions have rarely been modeled with respect to regional clusters.

Another limitation in the empirical research was sampling only one organizational form within clusters. For example, Sorenson and Audia (2000) sampled only shoe manufacturers, and many studies on biotechnology sampled only biotechnology firms and their initial public offerings (Noted exceptions: Powell et al., 2002; Stuart & Sorenson, 2003a). Counter to this trend, Boschma and Wenting (2007) looked at automobile manufacturing foundings related to labor market for coach and cycle making as well. In another notable study, Audia and colleagues (2006) looked at synergistic and competitive firms and firm founding. Audia, Freeman, and Reynolds (2006) used data from the US Department of Commerce's Benchmark Input-Output Account from 1977 and 1987 to determine purchasing from and selling to behaviors with other sectors. From those ratios, they calculated indexes for community supplier and purchaser synergy, and community competitiveness, for similar transactions as instrument manufacturers. The thoroughness of their calculations is impressive, however they too did not incorporate institutions in their models.

**Summarizing Technological Externalities Research**

Clearly, technological externalities benefit clustered firms. However, there has not been enough research to understand the influence of institutions on regional cluster formation. The researchers who studied the evolution of regional clusters neglected institutions (Boschma & Ter Wal, 2007; Klepper, 2005, 2007), or they study institutions and neglect regional clusters (Haveman & Nonnemaker, 2000; Sine et al., 2005). To improve our understanding about regional cluster development, researchers need to integrate models of institutions and regional clusters as interrelated industries. Institutional logics provide a framework for filling that gap. The next section explains how institutional logics are suited to understanding institutional influences on cluster emergence.

## Institutional Logics

As highlighted in the cluster literature review, the influence of institutions on regional clusters have been suggested but not tested (Russo, 2003 is a notable exception). And yet, researchers have suggested that the institutional environment is critical to the structure and flow of knowledge spillover and innovation (Malmberg & Maskell, 2006; Saxenian, 1994). Institutional logics provide a useful framing to represent and understand those institutional influences on cluster emergence.

Institutional theorists have developed the concept of institutional logics to represent belief systems that guide actions of organizations and actors (Friedland & Alford, 1991). Institutional logics represent:

> 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 & Ocasio, 1999: 804)

Institutional logics can influence action at many levels, and have been shown to exist at the level of geographic communities (Thornton & Ocasio, 2008). By influencing action at a geographic level, they provide a tool to predict institutional influences on cluster emergence.

**Prior Research on Institutional Logics**

Researchers have found direct and moderating influences of institutional logics on organizations. First, I review prior research showing direct effects, and then review the research in higher education publishing showing moderating effects (Thornton & Ocasio, 1999).

**Direct effects.** Logics focus attention on what individuals and organizations will find meaningful and what types of solutions they will perceive (Thornton & Ocasio, 1999). Lounsbury describes institutional logics as "broader cultural beliefs and rules that structure cognition and guide decision making in the field" (Lounsbury, 2007:289). Because organizational decision makers have limited resources for search processes, when they need to find a solution, they search within the vicinity of current solutions and knowledge (March, 1994). For example, consider an organizational decision maker looking for a waste solution. If the person has a pro-environmental logic guiding their thinking, then recycling is more likely to be perceived as a possible solution. Likewise, if this same person with a pro-environmental logic is interested in generating electricity, the person is more likely to see renewable energy technology as a possible solution, thus directly influencing organizational behavior.

Researchers have shown how replacement of dominant logics influences how fields change and mature (DiMaggio, 1991; Hoffman, 1999; Rao & Haveman, 1997; Thornton & Ocasio, 1999). DiMaggio (1991) showed how the conflicts between two differing logics lead to the eventual management model for art museums. Haveman and Rao (1997) showed how changes in demographics preceded the spread of Progressivism in banking. Moral sentiments, such as Progressivism, are supported by norms, rules, and ways of thinking encompassed by an institutional logic. Lounsbury (2002) tracked foundings of professional finance associations to show that a regulatory logic was replaced by market logic in the financial industry. Hoffman (1999) showed how the ideology of environmentalism went from fringe to core as chemical manufacturers developed a self-regulatory body. Additionally, many studies have shown how professionally based logics have been replaced by managerial logics (Meyer & Hammerschmid, 2006; Suddaby & Greenwood, 2005; Thornton, 2002). Business activities in organizational fields change as a result of the replacement of dominant institutional logics.

Contrary to earlier assumptions of inevitable isomorphic pressures, researchers have shown that organizational fields can contain multiple logics that compete or exist in a fragmented state (Lounsbury, 2007; Marquis & Lounsbury, 2007; Scott, 2001). Scott and colleagues (Scott, Ruef, Mendel & Caronna, 2000) studied the fragmentation of a dominant institutional logic in the U.S. medical field. They tracked the decline of the dominant association, the American Medical Association, and the rise of fragmented specialist associations. Lounsbury (2007) and Marquis and Lounsbury (2007) show that competing logics can coexist in the same organizational field. The existence of contradictory logics, such as community banking versus national banking, in heterogeneous geographical resource environments resulted in heterogeneous organizational fields with large national banks and smaller local community-based banks. Studying market management firms, Lounsbury (2007) found that geographically tied efficiency and performance institutional logics fragmented the institutional environment and resulted in heterogeneous firm practices. These phenomena run counter to the predictions of isomorphism.

**Moderating effects.** In addition to direct effects, institutional logics have been shown to have a moderating effect between economic and social motivations in business activities (Thornton, 2004). In her research on the higher-education publishing field, Thornton (2004) found that the moderating relationship of logics varied depending on the type of logic in use. She found that the editorial-logic had a greater moderating effect on executive succession than the market-logic. Thornton generalizes this finding to conclude that specific logics moderate business activities more than universal logics. Thus, for example, we may expect a specific logic focused on environmental sustainability to have a greater moderating influence on an entrepreneur's choice for electricity generation than a universal logic focused on profit margins.

## Geographically Bound Institutional Logics

We know institutions can vary geographically. As Scott (2001) states, "variation in institutional pressures also comes from differences over space and time in the strength of cognitive beliefs or normative controls" (: 162). Strangely, most of the institutional logic research has not considered geography. A few studies exist that have considered how geography and institutional logics are bound together. First, I review institutional logics research incorporating geography and then combine it with its potential for clusters.

**Geography and institutional logics.** Institutional theory researchers have considered how institutional heterogeneity results from imprinting and unique regional transformational processes. Marquis and colleagues show how imprinting effects influence firm activities in board composition (Marquis, 2003) and corporate social action (Marquis et al., 2007). Discussing the competing logics in the mutual fund industry, Lounsbury (2007) found that "practice variation was importantly connected to geographic heterogeneity, an often underappreciated dimension of organizational difference" (: 290). He found that these geographically bound logics in Boston versus New York City moderated economic pressures on contracting choices. Hall (2003) studied the persistent heterogeneity of local community institutions at the Baltimore port during an historic period of national pressures to convert to standardized containerization processes. He found that diversity in regions persist because regions undergo unique processes of regional institutional transformation in response to isomorphic pressures.

**Clusters and institutional logics.** Institutional logics can be and have been shown to be geographically tied to communities just as regional clusters are necessarily bound in a geographic region. Therefore, institutional logics ought to influence regional clusters and their emergence as well. Studying the emergence of the Branson, Missouri, musical theater cluster, Chiles and colleagues (2004) found that the unique, wholesome institutional environment was clearly imprinted in that particular geographic location. Romanelli and Khessina (2005) propose that clusters with stronger regional industrial identities will receive more resources such as investment and entrepreneurial location choices. In their model, regional industrial identity is the result of residents' and external audiences' perceptions of the region, heavily influenced by distinctive regional characteristics. Although they do not specifically discuss institutional logics, a strong perception of regional industrial identity could be akin to an institutional logic in its cultural-cognitive influence on business activities within a geographically bound region.

The influence of institutional logics on clusters depends on fit between a logic's guiding values and a regional cluster's business focus. Industries that are congruous with a specific institutional logic have a focus that fits with the institutional logic's guiding values. For example, Haveman and Rao (1997) showed that firm foundings in the early California thrift industry changed as demographic shifts in the region replaced the dominant institutional logic with Progressivism. Studying county level formation of wind energy projects in California, Russo (2003) found that the influence of regulatory institutions changed with the passage of PURPA, encouraging increasing clustering of qualifying facilities in conjunction with natural resources and social capital. Lee and Sine (2005) found that increases in state level Sierra Club memberships preceded state-level regulations and entrepreneurial filings of wind energy projects.

Influences of congruous logics occur between firms as well as between human populations and firms. Ingram and Simons (2000) found that in Israel other firm populations could influence focal firms' foundings and survival rates if they had similar ideologies. Carroll and Swaminathan (2000) found that specialist breweries increased their survival by highlighting their authentic alignment with the local regional identity. Chiles, Meyer, and Hench (2004) showed the importance of aligning with the institutional 'wholesome' values in Branson, Missouri, to the survival of new theaters.

Although Lounsbury (2007) did not study clustering of money market funds in Boston and New York specifically, the identification by city indicates a consensus on clustering of type of firm and institutional logic. Lounsbury (2007) argues for the need for more research on the shaping of organizations and industries by geographic heterogeneity and its corresponding logics. No one has studied how these geographically heterogeneous institutional logics influence clustering. Firm activities and foundings, which are necessary for regional cluster emergence, display a non-random pattern in conjunction with the institutional environment. Clearly institutions matter, yet how institutional logics influence regional cluster emergence has been under-studied.

## Summary of Cluster Research

Regional clusters are growing in importance as globalization makes geographical uniqueness more important in maintaining valuable, rare, inimitable, and nontransferable resources. Regional clusters, an overlooked level of analysis (Tallman et al., 2004), create an opportunity to study the interaction of organizations and their environments that create this geographical uniqueness. Researchers have examined the emergence of industries, but few have studied emergence of naturally occurring regional clusters (Fromhold-Eisebith & Eisebith, 2005). The empirical literature review highlights several opportunities to contribute to research on regional clusters. The contributions of this study are:

- Improving sampling across all firms rather than just firms within retrospectively identified clusters
- Modeling regional clusters as interrelated firms rather than one organizational form

- Modeling both regulatory and cultural-cognitive institutional influences on clusters
- Selecting a theoretical framework that incorporates institutions to use in the analysis of clusters

In order to increase understanding about clustered firms, they must be compared to non-clustered firms. For obvious tractability reasons, Chiles and colleagues (2004) studied only musical theater foundings within the Branson, Missouri, musical theater cluster. Left censoring on cluster samples is another sampling concern. Increasingly, researchers are beginning to encompass entire history of industries in their research or they identify discrete events to tether the sampling timeline.

The review of the literature highlights the need for improvement in sampling more than one organizational form (Audia et al., 2006; Freeman et al., 2006). Understanding more than one organizational form is definitionally important to regional cluster research and the applicability of the research. Public policymakers consider clusters as interrelated industries and institutions; as such, they cannot easily use the findings of population ecology researchers. Modeling the density of only one organizational form limits the understanding of how other organizations, institutions, and history affect regional cluster development. Some researchers used contextual knowledge of the setting to decide on salient organizations and institutions (Powell et al., 2002; Russo, 2001; Sine et al., 2005). Another way to determine interrelated industries is through industry input and output data (Audia et al., 2006). The thoroughness of their calculations is impressive, however they did not incorporate institutions in their models.

The research in regional clusters lack understanding about the interaction of organizations and institutions. Only a few studies modeled institutional influences on firm performance, particularly when looking at clusters. Those notable exceptions are Saxenian (1994), Russo (2003), and Chiles and colleagues (2004). All of the articles of Wes Sine and co-authors (2005, 2007, 2009) model institutions, but they do so at the state level, which is far too large a geographic unit to represent a cluster. Nor do they seek to identify clusters in their data, rather looking at project filing density aggregated at a state level.

Chiles and colleagues' (2004) study is one of the few to look at the institutional activities and mechanisms involved in cluster emergence. The rarity of these studies may be due to difficulty in capturing all relevant historical data. For example, Chiles and colleagues studied 100 years of local history. However, by waiting until a region has a clearly identified cluster, a researcher gives up access to much potential data and is reliant on retrospection and archival data sets.

Reviewing the literature in regional clusters is difficult because of the many diverse streams arising from different research disciplines. Given the numerous levels of analysis possible in regional clusters, no singular theory or discipline is the best fit for all levels of analysis. However, to maximize the insight the different disciplines have to offer researchers should select a theoretical framework that brings in externalities and institutions in order to allow for endogenous change and increasing returns (Arthur, 1994) in regional clusters.

This notable gap in understanding points to the need to study how geographically varying institutions influence regional clusters. Institutional logics present a means to identify and measure institutional influences on clusters. The next chapter builds the theoretical connection between institutional logics and levels of clustering and presents hypotheses to test the influence of institutions on the emergence and growth of regional clusters.

# CHAPTER III

# THEORETICAL FRAMEWORK AND HYPOTHESES

As reviewed in the previous chapter, research and observation indicate a tendency for firms to cluster in geographic regions. Researchers from the diverse intellectual traditions of industrial organizations, economic geography, management, and sociology have explored cluster emergence and sought to explain it. Much of this research builds from an underlying assumption that clusters form because they provide benefits, and has centered on identifying the benefits that accrue to clustered firms and industries. However, while we know access to resources, competitive effects, and knowledge spillover are some of the benefits to established clusters, much remains unexplained about institutional influences on cluster emergence and growth. Although prior literature alludes to the importance of institutions (Malmberg & Maskell, 2006; Saxenian, 1994), beyond influences of specific regulatory changes (Russo, 2003), we know little about how institutions influence clusters. This study seeks to fill that gap by asking the research question: *How do institutions, specifically varying levels of a congruous institutional logic, affect regional cluster emergence?*

Institutional logics, belief systems that guide actions of organizations and actors (Friedland & Alford, 1991), are a tractable way to conceptualize institutional influence on organizational activity in a region. For example, an institutional logic supporting community banking over national banking results in more locally owned banks (Marquis & Lounsbury, 2007). Institutional logics bring institutions down to a manageable level of analysis because they define "the meaning and content of institutions" (Thornton & Ocasio, 2008: 100). Institutional logics are useful for studying regional clusters because they develop and exist at many different levels, including geographic communities (Thornton & Ocasio, 2008). Thus, they can be applied to this study's definition of regional clusters as "geographically proximate group[s] of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities" (Porter, 1998: 199).

In the next section, I use the theoretical framework of institutional logics to build hypotheses to answer the research question. The hypotheses contribute to the theoretical literature on institutional logics by positing the influence of varying levels of a congruous institutional logic on regional clusters. Additionally, because uncertainty magnifies the institutional pressures on business activities, I explore the role of technological uncertainty on regional cluster emergence.

## Institutional Logics

According to Thornton and Ocasio, institutional logics represent:

> 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 & Ocasio, 1999: 804)

Thus, institutional logics are culturally constructed models that influence how actors interpret and resolve institutional pressures (Friedland, 2002). These institutional logics represent collective systems of meaning that influence practice. For example, Thornton (2004) showed how a shift from an editorial logic to a market logic in higher-education publishing changed which executives were promoted. As market logic began to dominate, executives who increased profits were promoted over those who increased the prestige of a firm. In another example, Lounsbury (2002) tracked foundings of professional finance associations to show that a regulatory logic was replaced by a market logic in the financial industry.

Logics focus attention on what individuals and organizations will find meaningful and what types of solutions they will perceive (Thornton & Ocasio, 1999). Because organizational decision makers have limited resources for search processes, when they need to find a solution, they search within the vicinity of current solutions and knowledge (March, 1994). However, institutional logics do not result from organizational fields, "they are locally instantiated and enacted in organizational fields as in other places such as markets, industries, and organizations" (Thornton & Ocasio, 2008: 119). For example, within the organizational field of U.S. banks, Marquis and Lounsbury (2007) found community banking logics at different levels in different communities. The presence of community banking logics influenced the types of banks in those communities.

As highlighted in the literature review, a growing area of research is how institutions at the community level influence organizational behavior (Marquis, 2003; Marquis et al., 2007; Marquis & Lounsbury, 2007). The juxtaposition of institutional logics and communities provides a solid, and yet new, opportunity to study the influence of institutions on regional clusters.

Although institutional theory has not been used to analyze regional clusters, it has been applied to the context of communities. Communities influence organizations through their differing institutional environments (Marquis & Battilana, 2009, forthcoming). As a level of analysis communities are:

> corresponding to the populations, organizations, and markets located in a geographic territory and sharing, as a result of their common location, elements of local culture, norms, identity, and laws" (Marquis & Battilana, 2009, forthcoming: 10-11).

These local environments provide heterogeneous institutional environments. As Scott states, "Variation in institutional pressures also comes from differences over space and time in the strength of cognitive beliefs or normative controls" (Scott, 2001: 162). Communities are the same level of analysis used in regional cluster research. As such, it is an appropriate concept for regional cluster analysis. Marquis and Battilana (2009, forthcoming) argue for more research at the community level to allow for understanding of local influences on organizations.

In order to apply institutional logics to clusters, I develop three hypotheses. First, I develop the theory on how institutional logics directly influence clustering. Second, I develop the theory on how institutional logics moderate pecuniary and technological externalities. Third, I develop the theory on how technological uncertainty moderates institutional logics direct influence on clustering.

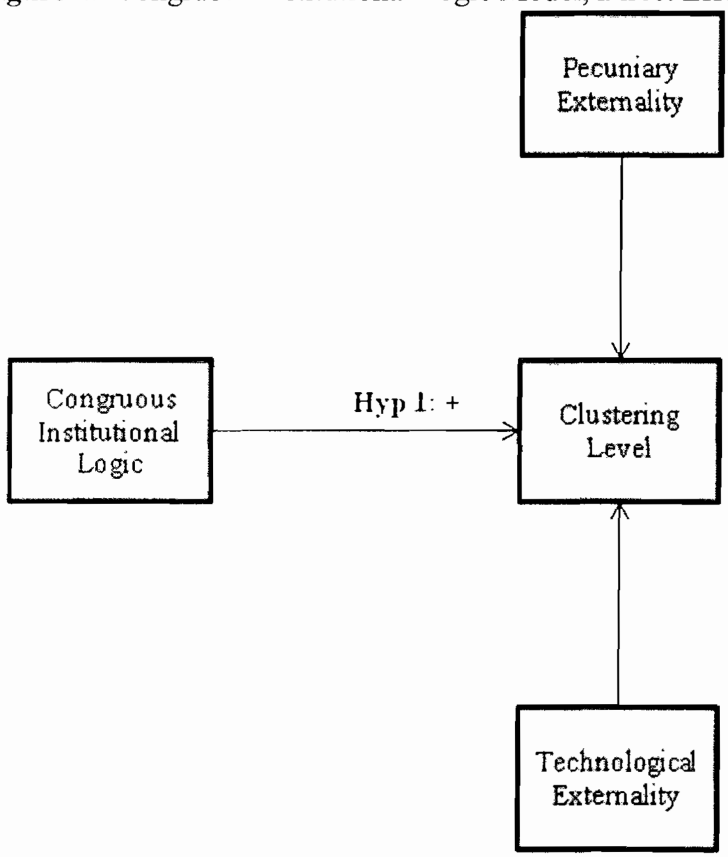
**Direct Influence of Congruous Institutional Logics on Clusters**

The influence of institutional logics on clusters depends on alignment between an institutional logic's guiding values and a regional cluster's business focus. An institutional logic is congruent with an industry, if the industry aligns with the same beliefs. For example, Haveman and Rao (1997) showed that firm foundings in the early California thrift industry changed as demographic shifts in the region shifted the dominant institutional logic toward Progressivism. Carroll and Swaminathan (2000) found that specialist breweries increased their survival by highlighting their authentic alignment with the local regional identity. Lee and Sine (2005) found that increases in state level Sierra Club memberships preceded state-level regulations and entrepreneurial filings of wind energy projects. The supportive influences of a congruous institutional logic occur at the national as well as state level. Ingram and Simons (2000) found that in Israel other firm populations could influence focal firms' foundings and survival rates if they have similar ideologies.

Studying the competing logics in the mutual fund industry, Lounsbury (2007) found "practice variation was importantly connected to geographic heterogeneity, an often underappreciated dimension of organizational difference" (: 290). He found that these geographically bound logics in Boston versus New York City influenced contracting choices such that firms contracted with firms that fit their specific institutional logic. Lounsbury (2007) argues for the need for more research on the shaping of organizations and industries by geographic heterogeneity and its corresponding logics. Institutional logics can and have been shown to be geographically tied to communities just as regional clusters are necessarily bound in a geographic region. Studying the emergence of the Branson, Missouri, musical theater cluster, Chiles and colleagues (2004) found that the unique, wholesome institutional environment was clearly imprinted in that particular geographic location.

Firm activities and foundings, which are necessary for regional cluster emergence, display a non-random pattern in conjunction with the institutional environment. Given representation of a congruous institutional logic, a positive influence should lead to higher levels of clustering by firms who align with that particular institutional logic.

**Figure 1.** Congruous Institutional Logic Model, Direct Effect




This direct influence of a congruous institutional logic on levels of clustering leads to the first hypothesis. Institutional logics are heterogeneous across communities leading to different outcomes in firm activities and levels of clustering in communities. It can be expected that congruous institutional logics will directly influence the level of clustering of industries that are congruent with the belief system of a specific institutional logic.

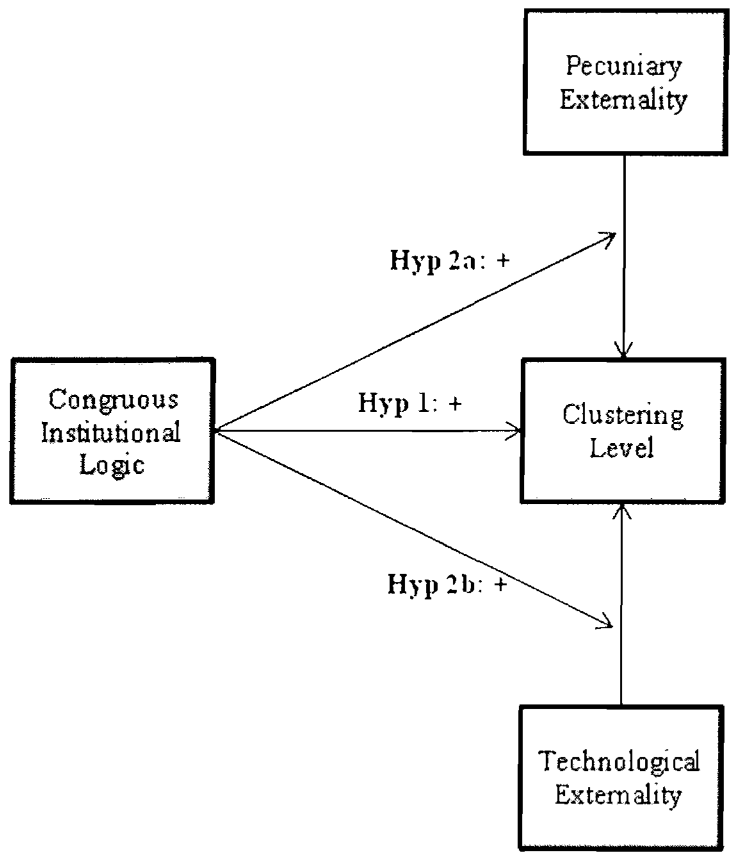
**Hypothesis 1: The relationship between congruous institutional logics and clustering is positive: Higher levels of congruous institutional logics will be associated with higher levels of clustering.**

### Moderating Influence of Congruous Institutional Logics on Clusters

In addition to a direct effect, institutional logics have shown a moderating effect (Thornton, 2004). As highlighted in the literature review, positive pecuniary and technological externalities are a key mechanism explaining cluster growth. Since institutional logics guide how people think and make decisions (Lounsbury, 2007), they are likely to influence how pecuniary and technological externalities are used by firms. For example, a pecuniary externality in a cluster could be from labor pooling, resulting in reduced costs for labor inputs. If the institutional logic resonates with individuals with the necessary labor skills, then it will enhance the benefits from that pecuniary externality on clustered firms. In another example, a technological externality of knowledge spillover from public research organizations could be enhanced if the institutional logic resonates between the source of the knowledge spillover and the clustered firms. It reasons that if researchers and managers share an institutional logic, there will be more interaction and more exchange of knowledge. Saxenian (1994) found that collaborative funding was institutionalized at Stanford in Silicon Valley, and hierarchical funding was institutionalized at MIT in Boston. When combined with the more collaborative and open business atmosphere in Silicon Valley, it resulted in greater knowledge spillover and entrepreneurial activity in Silicon Valley.

In her extensive study of publishing in higher education, Thornton (2004), found that institutional logics had a moderating relationship between economic and social motivations in business activities. She found that the moderating relationship of logics varied depending on the type of logic in use. She found that the editorial-logic had a greater moderating effect on executive succession than the market-logic. Thornton generalizes this finding to conclude that specific logics moderate business activities more than universal logics. Thus, for example, we may expect a specific logic focused on environmental sustainability to have a greater moderating influence than a universal logic focused on profit margins on an organizational decision–maker's selection of geographic location. For this reason, it can be expected that specific institutional logics will have a moderating influence in addition to a direct influence on levels of clustering.

**Figure 2.** Congruous Institutional Logic Model, Direct and Moderating Effect




This moderating influence of a congruous institutional logic on the direct influence of externalities on levels of clustering leads to the next two hypotheses. Institutional logics and pecuniary and technological externalities are heterogeneous across communities leading to different outcomes in firm activities and levels of clustering in regions. It can be expected that congruous institutional logics will increase the positive relationship between increasing pecuniary or technological externalities and cluster growth.

**Hypothesis 2a: The moderating relationship of congruous institutional logics on the influence of pecuniary externalities on clustering is positive: Higher levels of congruous institutional logics will strengthen the positive relationship between positive pecuniary externalities and clustering.**

**Hypothesis 2b: The moderating relationship of congruous institutional logics on the influence of technological externalities on clustering is positive: Higher levels of congruous institutional logics will strengthen the positive relationship between positive technological externalities and clustering.**

This study tests the direct and moderating influences of congruous institutional logics on clustering. However, the type of industry cluster may interact with this relationship. A key dimension to understanding institutional influences on industry relates to its level of uncertainty (DiMaggio & Powell, 1983).

## Technological Uncertainty

When using an institutional framework to examine the influence of institutional logics on business clustering, it is important to consider the impact of uncertainty. When facing uncertainty, decision-makers look to institutional sources for information to guide them in making decisions. These decisions directly affect firm activities and subsequently clustering of firms. Institutional influences are stronger under greater levels of uncertainty (DiMaggio & Powell, 1983). Marquis and colleagues (2007) show how community isomorphism leads to differing organizational practices. When a business practice has higher levels of uncertainty, such as corporate social action, firms are more likely to look to norms within their local geographic communities for legitimacy. Davis and Greve (1997) found geographically proximate firm activities were more influential when the value of a business practice was uncertain. Studying cooperative technical organizations, Rosenkopf and Tushman (1998) found that as technological uncertainty increases, the importance of social construction processes on the development and implementation of technology increased.

Uncertainty amplifies the influence of institutions on firm activities. Technology represents one important type of uncertainty (March & Olsen, 1976) affecting the influence of institutions (DiMaggio & Powell, 1983). Technological uncertainty results from a lack of knowledge about the technology's risks (Wejnert, 2002). Since clusters form around an industry or technology, technological uncertainty is essential to understanding how institutional logics will influence levels of clustering. In order to understand how institutions influence clustering, we need to explore the role of technological uncertainty.

The process of technology adoption and diffusion is influenced by social as well as economic factors (for reviews see Gopalakrishnan & Damanpour, 1997; Wejnert, 2002). The technology adoption process has three stages (Rogers, 1995). Rogers's (1995) diffusion of innovation model represents a decision-based process of cognition-evaluation-connotation. Cognition involves awareness of a technology, evaluation involves determining if the innovation is better than alternatives, and connotation involves implementing a technology.

Several characteristics influence adoption, including relative advantage, compatibility, complexity, trialability, and observability. Social structures and processes, including institutional logics, infuse meaning into the messages received about a technology concerning its relative advantage compared to other technology. Additionally, compatibility is socially influenced by the decider's experiences and values. Technology adoption is therefore a process of acceptance and use, led by awareness which is more socially determined, and followed by implementation which is constrained by economic resources and environment. The growth of business clusters focused on wind or solar power generation is essentially affected by rate of adoption of those technologies by entrepreneurs and existing and potential customers.

Whether and how a technology is used is greatly influenced by institutional pressures (Martinez & Dacin, 1999). Wejnert (2002), in her review of diffusion of innovations, shows the importance of environmental conditions, including beliefs and values, on innovation adoption and diffusion. Very relevant to cluster emergence, she argues that externalities allow for the adoption of technologies. The greater the ambiguity around the costs, the more need to guess and place value judgments on using a technology. For example, the Baltimore Port Authority, with its community specific institutions, resisted the standard adoption of containerization equipment and facilities, resulting in the port adopting differing approaches to the technology (Hall, 2003). How local cultural beliefs, akin to institutional logics, have influenced the adoption of technologies has been studied in agricultural economics in the adoption of sustainable practices. The belief systems of Amish communities are congruous with sustainable practices leading to greater levels of adoption (Sommers & Napier, 1993). Particular

Montana communities with a culture of support for sustainable practices led to greater adoption by farmers of sustainable practices in those communities (Saltiel, Bauder & Palakovich, 1994).

Researchers have demonstrated positive relationships between institutional legitimacy and foundings based on new, uncertain technology in renewable energy. Research by Russo (2001; 2003) and Sine and colleagues (Lee & Sine, 2005; Sine et al., 2005) show the importance of social, in addition to economic factors in founding of renewable energy projects. Russo (2003) found increases in project density as a measure of cognitive legitimacy lead to more wind energy project foundings. Sine and colleagues (2005) found that greater levels of legitimacy for small power generation using both traditional and novel technology increased firm foundings, but in particular, normative legitimacy with state associations increased traditional, less risky, technological foundings. Comparing established brown technology foundings to novel green technology foundings supports the importance of cognitive legitimacy to adoption of uncertain technology. "Because brown technologies were better-understood technically, had lower development costs, and were more culturally established than green technologies, they were generally less risky bases for new ventures than green technologies." (Sine et al. 2003: 215) Lee and Sine (2005) argue that the social awareness of Sierra Club members regarding wind energy preceded regulatory and economic incentives that encouraged wind energy foundings.

Awareness and value of technology can be concentrated in a community through the presence of populations with particular institutional logics or technologically enabling resources. In a study of adoption of home solar systems in Sri Lanka, villages with more minorities, representing an attitude of greater self-reliance, were more likely to adopt the new technology (Mceachern & Hanson, 2008). In communities possessing necessary resources such as individuals with professional banking experience, community banks were more often founded in resistance to national institutional pressures during a time when there was pressures toward consolidation (Marquis & Lounsbury, 2007). Sorenson and Audia (2000) found that shoe manufacturers clustered where entrepreneurs were able to recognize opportunities because of prior experience in shoe manufacturing. Because institutional logics funnel individual's recognition of problems and possible solutions, it follows that logics will influence what entrepreneurial opportunities are recognized and thus where clustering may follow.

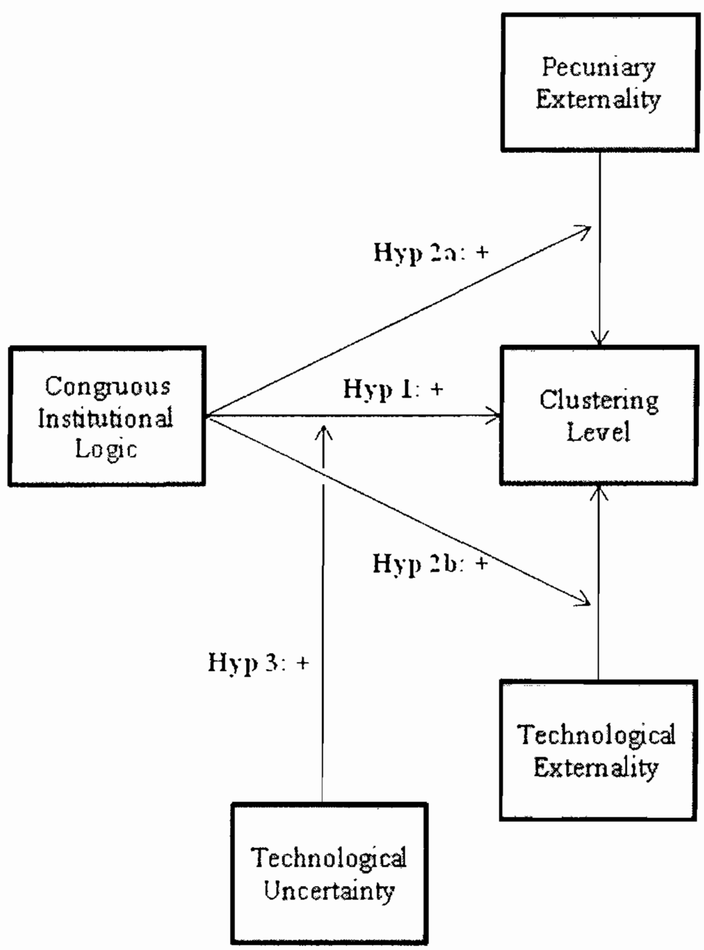
Researchers have conflicting accounts of how technology spreads geographically. Brown (1981) characterizes geographic diffusion of technology as originating from a point and spreading outward over spatial distance. This suggests that adoptions will spread from population centers where more information about the technology is available (Brown, 1989) or from where the technology is manufactured. Researchers argue that this type of positive feedback greatly influences the emergence of business clusters (Porter, 1998b). Ideology, a different mechanism than postulated by Brown for geographically centered diffusion, may also facilitate diffusion to communities with similar ideology. The importance of similar ideologies explained the spread of decolonization among colonies more than geographic proximity (Strang & Tuma, 1993). Both mechanisms may act concurrently in diffusion of technology. Geography is important not only to outward diffusion, but heterogeneous communities may have unique intensity of institutional logics that also are important to the diffusion of technology even when not geographically proximate.

Although not intentionally studying competing logics, or cluster emergence, Sine and colleagues (2005) found in their study of overall levels of organizational diversity in small power foundings in California and New York, that the likelihood of using brown technologies was significantly negative in California. This finding could be the result of an environmentally sustainable logic in California that was absent in New York. At the beginning of the small power generating industry in the U.S., increasing regulative and cognitive legitimacy increased founding for novel technologies more than it did for traditional technologies. However, we do not know how geographically linked institutional logics may affect clustering of firms or customers for these green technologies. There are hints that institutional logics can influence technology adoption in Sine and colleagues' (2007) research: "Green-technology entrepreneurs who advocated wind power showed that they rarely built gas cogenerators if the price of natural gas declined. Instead, they waited until they were able to mobilize the necessary resources to use their preferred technology" (Sine et al, 2005: 227). In communities where these environmentally sustainable institutional logics are prevalent, adoption of uncertain green technologies is more likely.

My study uses two different renewable energy technologies around which regional clusters may emerge. Both technologies align with an environmentally sustainable logic, which allows for the influence of technological uncertainty in combination with institutional logics to be examined more clearly.

Given that logics are place bound (Lounsbury, 2007; Marquis & Lounsbury, 2007) and that specific logics, such as environmentalism, have more influence than universal logics such as profit maximization (Thornton, 2004), we can expect that alignment with particular logics in the institutional environment will be more important when a technology's commercial viability is more uncertain. The importance of institutional pressures on given technological uncertainty will affect clustering for firms that align with a particular congruous logic.

**Figure 3.** Congruous Institutional Logic Model, Uncertainty Moderating Effect



It can be expected that technological uncertainty will increase the positive relationship between a congruous institutional logic and cluster growth.

**Hypothesis 3: The moderating relationship of technological uncertainty on the influence of a congruous institutional logic on clustering is positive: Higher levels of technological uncertainty will strengthen the positive relationship between congruous institutional logics and clustering.**

In the next chapter, I explain the empirical setting, sampling, and analytical techniques I use to test the hypotheses. Following that, the fifth chapter presents the empirical results and the sixth chapter follows with conclusions and implications.

# CHAPTER IV

# RESEARCH METHODOLOGY

Despite interest in regional cluster emergence and more than a century of research, the phenomenon contains subtleties that researchers have failed to explain. As highlighted in the literature review, there is a gap in understanding how institutions influence regional cluster emergence. This leads to the guiding research question: *How do institutions, specifically varying levels of a congruous institutional logic, affect regional cluster emergence?*

In order to address this gap, this chapter reviews the empirical setting, sample, data collection, operationalization of variables, and analysis plan for testing the hypotheses presented in the previous chapter. Determining how institutional logics influence cluster emergence requires that institutional logics be identified and measured. This study uses the congruous relationship between firms whose activities are perceived to be pro-environmental with the prevalence of the pro-environmental institutional logic of a human population. By capitalizing on previous research in this context by Russo (2001, 2003) and Sine and colleagues (2005, 2005, 2007), and introducing a variable to represent pro-environmental institutional logic, the present study increases understanding of regional cluster emergence.

This chapter begins with an explanation of the research method employed. Then I discuss the empirical setting, which greatly influences the sample design and sampling frame. This is followed by an explanation of data sources and operationalization of the variables. Finally, I explain the estimation methods used for the analysis presented in the next chapter.

## Description of Research Method

This study hypothesizes a causal relationship between congruous institutional logics and levels of firm clustering that align with a particular logic. Testing institutional influences on regional cluster emergence necessitates a longitudinal study (Thornton & Ocasio, 2008). Previous research about institutional influences on regional cluster emergence have used either quantitative panel data (Audia et al., 2006; Russo, 2003) or qualitative data (Chiles et al., 2004; Saxenian, 1994). The perspective afforded by the use of panel data does have disadvantages compared to qualitative data. Qualitative data affords the ability to understand the finer nuances of institutional influences within a particular context. However, panel data allows this study to maximize the variation in the variables of interest by sampling across many regions and many years. As such, this study employs panel data methods in conjunction with interviews to provide contextual understanding.

Using panel data across many regions allows me to avoid sample selection errors resulting from sampling on the dependent variable of a previously recognized cluster. I build the panel data set using archival data sources. Advantages of archival data are the ability to cover long periods of time, and track large populations of firms (Hoyle, Harris

& Judd, 2002). Care needs to be taken wherever archival data measures are used, in order to avoid distorting their representation of the focal constructs in the analysis. To overcome these potential misspecification errors, the research is grounded by interviews to contextualize the construct variables. Next, I explain the empirical setting for this study and how it allows for representation of an institutional logic of environmental sustainability.

## Empirical Setting

The research setting is the renewable energy manufacturing industry. Renewable energy is "power generated by the natural processes of wind, sun, water, plant growth, and heat from the earth being converted into power, steam and heat" (Repp-Crest, 2008). The intent of developing renewable energy is that it should be nearly inexhaustible but limited in the amount of energy generated per unit time in comparison with petroleum, natural gas, coal, or other extractive energy sources (Repp-Crest, 2008). The Department of Energy considers biomass, hydropower, geothermal, solar, wind, ocean thermal, wave action, and tidal action to be renewable energy sources (EIA, 2004). Another benefit of renewable energy is its comparatively small impact on the environment as an alternative to burning conventional fuels. Pro-environmental organizations, such as the Sierra Club, Friends of the Earth, and the National Audubon Society, started paying attention to its potential around 1970 (Mitchell, Mertig & Dunlap, 1992). In the late 1970s, pro-environmental organizations began promoting renewable energy as an important mechanism to protect the environment (Mitchell et al., 1992). Traditional power generation became known for degrading the environment, while renewable energy generation became known as better for the environment (Sine & Lee, 2009). A pro-environmental institutional logic fits, or in other words, is congruous with, the renewable energy industry. Regions with higher levels of a pro-environmental institutional logic thus are congruous with clusters of renewable energy manufacturing.

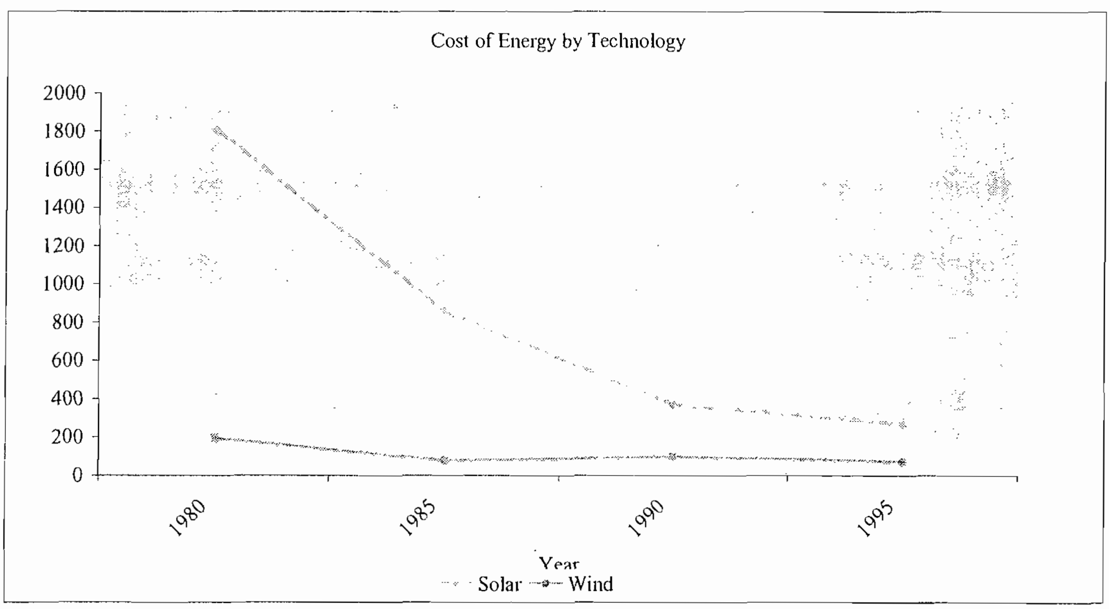
The timeframe begins with the modern emergence of the renewable energy industry in the United States, with the passage of the Public Utility Regulatory Policies Act (PURPA) of 1978 (Russo, 2001). Provisions in PURPA required electric utilities to purchase generated energy at an avoided cost rate from qualifying facilities, where qualifying facilities are non-utility electricity generators that meet certain ownership, operating and efficiency criteria established by Federal Energy Regulatory Commission (FERC) (Administration, 1996). Although the variation in how states and utilities interpreted and accounted for avoided cost rates greatly influenced the filing for renewable energy projects (Russo, 2001), as such the passage of PURPA also supported the development of the renewable energy industry.

The sample goes through 1995, which was a watershed year for the wind energy industry for several reasons. First, the provisions of the Energy Policy Act of 1992 were affecting the utility market such that energy wholesalers, such as Enron, could become non-utility energy producers. Second, in 1995 a court case against the California Public Utility Commission supported the Federal Energy Regulatory Commission's (FERC) enforcement of capping contracts to qualifying facilities at the avoided cost rate and no higher (Doe-EIA, 2008). This resulted in avoided cost rates lower than the interpretation by several states, including California (EIA, 2005). Third, specific to California, where nearly all non-renewable capacity was located until the early 1990s, prices paid to renewable energy producers dropped drastically in the mid-1990s (EIA, 2005). Ten-year Standard Offer projected avoided cost rates based on the high oil prices in the early 1980s. California's avoided cost rate, set by California's Public Utilities Commission in 1982, was based on forecasted oil and natural gas prices, after 10 years the contracts reverted to actual avoided cost rates. Most of California's wind capacity was installed under these Interim Standard Offer 4 contracts starting in late 1983. Contracts initiated in 1984 and 1985 began to expire, and the new avoided cost rates were about half as much; they dropped from 6.9 cents per kilowatt-hour to about 3 cents per kilowatt-hour. This "11-year cliff" (EIA, 2005) referred to the dramatic price decrease received by QFs at the expiration of the 10-year contracts. The "11-year cliff" reduced commercial viability of renewable energy producers in California (Chapman & Wiese, 1998), and as such was a pivotal time in the renewable energy industry.

The creation of a commercial domain for non-utility generated electricity established new markets for the renewable energy industry. This study uses the renewable energy industry to understand institutional influences on clusters. The only researcher to study clusters of alternative energy projects was Russo (2003), performed at the county level in California. However, he was studying the clustering of wind energy generating facilities—one organization form. As this study uses the same setting but studies the clustering of supply-chain clusters for alternative energy *manufacturers*, and represents these alternative energy qualifying facilities as informed customers and operationalizing clusters as inter-related firms, the present study adds to the understanding presented by Russo's (2003) analysis. Additionally, this study examines the varying influence of congruous institutional logics on two distinct renewable energy technologies: wind and solar. By using different technologies with drastically different commercial viability, the nuanced influence of institutional logics can be teased apart.

Wind and solar energy technologies had very different levels of uncertainty associated with them from 1978 to 1995. One representation of uncertainty is the cost of energy (COE) produced. COE incorporates capital, fuel, and operation and maintenance costs. As you can see in Figure 4, the projected COE was drastically different between the two technologies (Mcveigh, Burtraw, Darmstadter & Palmer, 1999). Although projected COE for solar steadily decreased over time, it did not come close to the COE for wind energy generation.

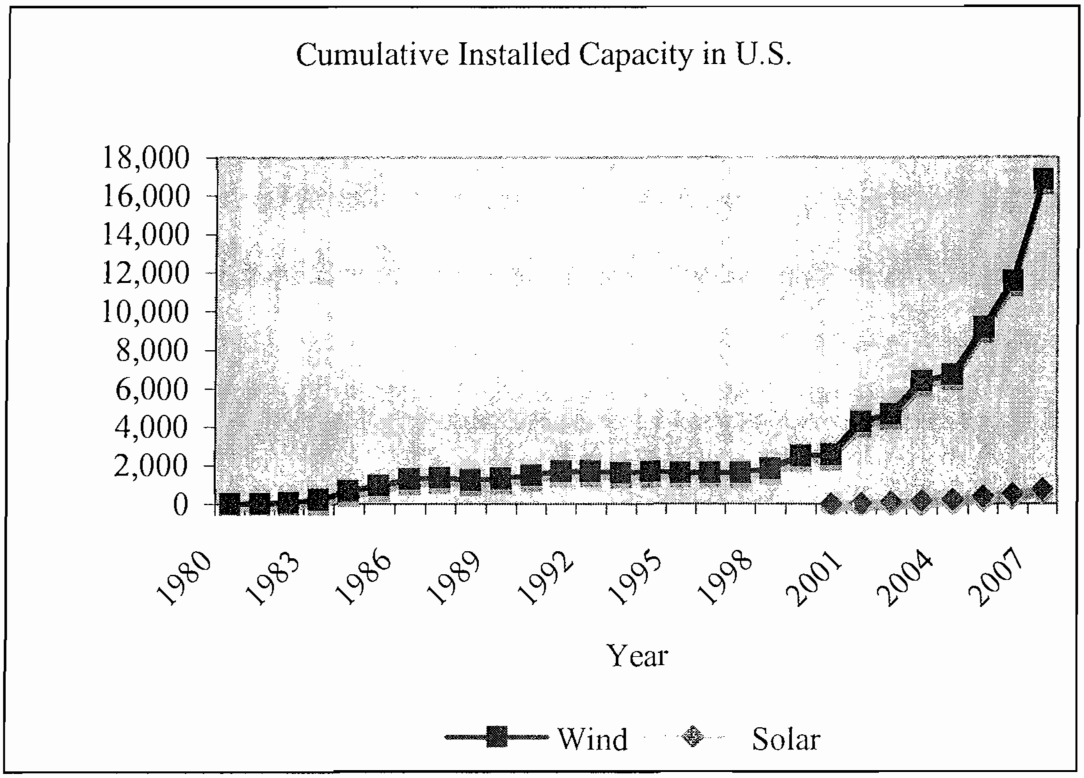
**Figure 4.** Projected Cost of Energy Produced for Wind and Solar from 1980 - 1995




During the time period for this study, 1978-1995, wind energy technology had settled on its dominant form while solar energy technology had not settled, and is in fact still under contention in 2009. Wind energy technologies are dominated by vertical and horizontal axis wind turbines (Gipe, 1995). Despite large federal support of research and development of both types of turbines, the vertical turbines experienced technological and commercial dead ends in the 1970s and 1980s (Gipe, 1995). By 1982, it was clear that the U.S. wind farm market would be dominated by horizontal three-blade upwind designs (Dodge, 2001). For example, in 1995, 94% of California's generating capacity used the horizontal three-blade designs, while the remaining 6% used the vertical axis designs (Gipe, 1995). Solar energy technologies include photovoltaic and concentrating solar power. Neither technology, nor even the dominant technology standard between thin-film or crystallized silicon photovoltaic cells, has been resolved to date (Terlaak & Gong, 2009).

Another representation of uncertainty is implementation of technology. When energy generation facilities are installed, the demonstration of a technology's viability decreases its uncertainty. Generation facilities for wind increased since the 1970s but solar and photovoltaic energy generation was only in niche markets and remote applications (Mcveigh et al., 1999). Figure 5 shows cumulative installed capacity in the U.S. for wind energy and solar energy. Information on installed wind capacity was available starting in 1980 (Dorn, 2008). Information for solar capacity was only available starting in 2000 (Bradford & Maycock, 2007). However, you can see as early as 2000 that only 17 Megawatts of solar capacity were installed, compared to 2,578 Megawatts for wind capacity. When uncertainty is greater, entrepreneurs are less likely to use a technology. The graph below show the greater installation of wind energy is an indication of its greater certainty over solar energy technology.

**Figure 5.** Cumulative Installed Generation Capacity for Wind and Solar from 1980-2007




The difference in uncertainty between the two technologies is used in testing hypotheses 3: that increasing uncertainty increases the influence of congruous institutional logics on cluster emergence. The estimation methods employed are explained at the end of this chapter in the section on statistical estimation. In the next section, I explain the sample design for this empirical setting.

Sample Design

As with any research project, delineating the scope of the study is essential for tractability. Although setting boundaries on the breadth of the study limits its generalizability, it greatly enhances its manageability. Since this study has a universalistic research goal, such that it is testing theoretically driven hypotheses, internal validity is more important than external validity (Hoyle et al., 2002). Internal validity is concerned with showing causal effects (Hoyle et al., 2002). To test for causality it is necessary to have longitudinal data. For this study, I gather annual data for each region from 1978 to 1995. In order to minimize censoring observations, the study begins at a significant point in the emergence of the industry and ends at a point of significant change: 1995. In the statistical estimation section at the end of this chapter I explain the Granger causality (Granger, 1969; Wooldridge, 2003) method used to determine whether the relationships between variables is spurious or causal, and if so, the direction of causality.

This study does not randomly sample among regions, rather it uses data on the population of regions in the U.S. This limits its external validity—the ability to generalize from the sample to the population and setting (Hoyle et al., 2002). However, since this study has a universalistic research goal, increasing the size of the sample to encompass the entire population increases the study's internal validity. Sample selection correction methods (Heckman, 1979) are used to adjust the estimation method for regions which are not represented because of missing data.

## Sample Frame

Sample frame is the population from which a sample is drawn (Hoyle et al., 2002). This study uses panel data of annual information from regions across the U.S. from 1978 through 1995. In this section, I explain the unit of analysis selected to represent geographical regions.

Geography is an essential dimension for studying regional clusters. Many researchers have identified clusters based on commonly held understandings that a particular city is a cluster, for example, an association is made between automobiles and Detroit (Klepper, 2007), or Boston and biotechnology (Owen-Smith & Powell, 2004). They then study the performance of firms based on locating in a cluster. For this study, focusing on one city or region is inadequate because the study aims to test the influence of varying levels of a congruous institutional logic across different regions. As such, an a priori identification of cluster locations would be selecting on the dependent variable.

Previous research examined clusters at three different geographic levels: 1) the state-county level (Henderson, 2003; Russo, 2003), 2) the Metropolitan Statistical Area (MSA) (Jaffe et al., 1993; Romanelli & Khessina, 2005), and 3) the Labor Market Area (LMA) (Audia et al., 2006). An advantage to using counties as geographic regions is that federal data are often aggregated at this level. A disadvantage is that regional clusters may span county borders. Comparatively, an advantage to using MSAs as a geographic region is that most manufacturing clusters occur within urban areas, while a disadvantage is that a cluster may occur in a rural area, possibly outside a MSA boundary. Additionally, there is a strong precedent for using MSAs to represent community based research (Marquis & Battilana, 2009, forthcoming). Comparatively, an advantage to using LMAs as a geographic region is that LMAs cover gaps between MSAs in areas with low population density and represent areas where people live and work. The disadvantage is that LMAs, particularly in sparsely populated areas, can be quite large geographically, creating a potentially implausible analytic frame. For example, Audia, Freeman, and Davidson Reynolds (2006), used LMAs to determine geographic regions in their analysis of instrument manufacturing communities. This unit of analysis results in an LMA that encompassed a quarter of the state of Montana. Considering the advantages and disadvantages of the three geographic regions as units of analysis, MSAs are best for this study because clustering is a predominantly urban phenomenon.

Since the US Census Bureau periodically updates the listing of MSAs, it is important that I clarify the unit of analysis for this study as 1999 United States MSAs. Where MSA is defined as:

> a core area containing a substantial population nucleus, together with adjacent communities having a high degree of economic and social integration with that core (US Census Bureau, 2008b).

The 1999 MSAs are based on the 1990 standards for defining metropolitan areas. According to the 1990 standards, a MSA must have a population of at least 50,000 people. If a metro area has greater than one million people, and distinct and yet contiguous MSAs are identified within it, the greater area is designated as a Combined Metropolitan Statistical Area (CMSA) and the component MSAs are called Primary Metropolitan Statistical Areas (PMSA) (US Census Bureau, 2008a). For example, New York City is a CMSA with 13 PMSAs such as Bridgeport, Connecticut, and Newark, New Jersey. This study analyzes all variables at the level of MSA and CMSA.

There are 276 MSAs in the 1999 U.S. Census Bureau listing. Twenty-four of the MSAs did not have population data in the Global Insight dataset. Six of the missing MSAs were not identified until the 1999 listing, six were not identified as MSAs until the 1995 listing, and three more were not official MSAs until the 1990 U.S. Census Bureau listing. The remaining ten missing MSAs were identified as MSAs at the start of the time frame in 1978, however, the data available on their annual populations in the Statistical Abstracts of the United States was incomplete for the time span of this study.

The time unit is annual. Since most variables are lagged, the time span is from 1979 to 1995. Due to a fixed effects transformation of the model, another year's data are absorbed. The justification for the fixed effects model is in the statistical estimation section at the end of the chapter. Eliminating MSAs in Puerto Rico and the Virgin Islands, and due to missing data on some MSAs that were not tracked in the 1970s, the data set contains 252 MSAs across 16 years results in 4032 observations. Three observations are lost because Spokane, Washington, had only one Congressional Representative until 1993. When Tom Foley was the Speaker of the House in the 101st to the 103rd congress and did not vote, there were no other Congressional Representatives to average into that particular MSA's score (missing scores are from the years spanning 1989-1991). Due to this, the number of observations used in analysis drops to 4029. I use a Heckit method to correct for selection bias (Heckman, 1979) resulting from 24 of the 276 MSAs that are not represented in the dataset because of missing population data. The Heckit method is explained at the end of this chapter, in the section on estimation methods.

## Data Collection

Data collection began with interviews of Public Service Commissioners and alternative energy professionals to understand the emergence of clusters within the context of solar and wind energy manufacturing. The intent of the interviews was to improve the construct validity of the cluster measure. Construct validity ensures the variables represent the constructs they are intended to represent (Hoyle et. al., 2002). For example, Porter (1998) identifies tourism as an important component in California's wine cluster. Although not all clusters have an industrially-unrelated component such as California's wine cluster does, simply examining inputs and outputs of viticulture would miss the tourism component.

Interviews focused on components of wind energy manufacturing or solar energy manufacturing clusters that went beyond inputs and outputs. Between July and October 2008, I interviewed five public service commissioners from Colorado, Massachusetts, Montana, and Maine, two renewable energy consultants, and three renewable energy professionals. Interviews indicated two things: 1) no clearly identified alternative energy clusters exist, and 2) other than input requirements, there are no other essential industries necessary for renewable energy manufacturing cluster.

For the most part, all of the people interviewed thought only about renewable energy generation, not the manufacturing of the systems and components. They did not think of one particular region where they sourced for new generations facilities. For example, Frank Burkharstmeyer, a renewable energy professional whose career has spanned Pacific Power, Scottish Power, and Iberdrola Renewables, when asked about potential renewable energy *manufacturing* clusters stated:

> No, not really, there are clusters of wind projects. But I don't know of any clusters of manufacturers. I know we try to get the towers as close as possible because hauling them is difficult (Burkhartsmeyer, 2008).

The interviews improved my contextual understanding about the industry but did not identify any unusual industries that might be involved with a renewable energy manufacturing cluster. I used industry reports to identify essential inputs to renewable energy manufacturing. Essential inputs are skilled labor, component manufacturing, and material suppliers. The list of components for wind and solar energy systems used for identifying component manufacturers is in Appendix B.

## Data Sources and Operationalization of Variables

In this section, I describe each variable selected for testing the hypotheses. I improve this study's discriminant validity by using the nominological net of how previous research represented these concepts (Hoyle et al., 2002). Previous research measuring a regions' pro-environmental proclivities has used League of Conservation Voter *Environmental Scorecard* scores (Delmas, Russo & Montes-Sano, 2007; Groseclose, Levitt & Snyder, 1999), I use this same metric to operationalize this study's explanatory variable. I followed previous research in this particular empirical setting by Russo (2001, 2003) and Sine and colleagues (2005, 2005, 2007) for selection of the control variables. Before describing each variable in detail, table 2 provides an overview of the variables to aid the reader.

**Table 2.** Summary of Operational Definitions for Variables

| Variable | Operationalization | Data Type |
|---|---|---|
| **Dependent Variables** | | |
| Level of clustering | Interrelated Location Quotient (ILQ) | Ratio |
| **Explanatory Variables** | | |
| *Institutional Logic* | | |
| Pro-environmental Population | Congressional Representative League of Conservation Voters Scores | Continuous |
| *Externalities* | | |
| Pecuniary Externalities | Skilled Labor Pool as Proportion of Manufacturing Labor | Continuous |
| Technological Externalities | University Research Spending | Continuous |
| Technological Externalities | National Laboratory | Indicator |
| **Control Variables** | | |
| *Demand Conditions* | | |
| Wind and Solar Energy Generators (QFs) | Federal Energy Regulatory Commission | Count |
| *Factor Conditions* | | |
| Quantity of Incentives | State Incentives, Solar Law Reporter | Count |
| Population | US Census Bureau, Global Insight | Continuous |
| Change in State GDP | US Bureau of Economic Analysis | Continuous |
| Average Price of Electricity | Energy Information Administration | Continuous |
| Wind and Solar Potential | National Renewable Energy Laboratories | Continuous |
| *National Market Conditions* | | |
| Federal Incentive | Federal Register | Indicator |
| Supreme Court Ruling | Solar Law Reporter | Indicator |
| Change in National GDP | US Bureau of Economic Analysis | Continuous |
| Interest rate | Federal Reserve Economic Data | Continuous |
| **Instrumental Variables** | | |
| *Davidson-MacKinnon Exogeneity Test* | | |
| State Electricity Imports | Energy Information Administration | Continuous |
| *Heckit Correction* | | |
| All Non-farm Labor | Bureau of Labor Statistics | Continuous |

**Dependent Variable**

Although clusters are defined as interrelated firms (Porter, 1998a), prior research rarely measured clusters of interrelated firms. Instead, prior research tended to measure density of one organizational form. This study improves on previous research by identifying interrelated firms and measuring their clustering. The dependent variable representing clustering is the Interrelated Location Quotient (ILQ). The justification and calculation for ILQ is explained in this section.

Determining interconnected firms for wind and solar energy projects can be accomplished through qualitative analysis, such as interviews, and/or quantitative analysis. The difficulty with seeking expert opinions on which firms are interrelated is the endogenous problem of pre-determining the clusters to be found based on those experts' experiences. One risk, therefore, is of quantitatively finding cluster emergence in the very place where such experts' work. An alternative approach to discovering the degree of firm interrelatedness is through use of a pre-existing metric for quantitative analysis and inference. The difficulty with using a quantitative analysis such as input-output ratios (Audia et al., 2006) lies in the researcher's capacity to capture those interrelated firms that do not use the same inputs or outputs. For example, the wine country cluster in California consists of wine producers and tourism (Porter, 1980), which use drastically different inputs.

As discussed in the literature review, most researchers dodge this difficulty by focusing on densities of only one industry or firm. O'Donoghue and Gleave (2004) reviewed commonly used agglomeration measures, unfortunately most focus on employment densities of one industry. This narrowly tailored sampling technique misspecifies the essential meaning of a regional cluster. As Audia, Freeman, and Reynolds stated (2006):

> confining the analysis to the demography of single populations, or to the study of a small set of similar forms, may severely constrain our ability to explain the trajectories of organizational populations. (:384)

Thus to understand clusters of organizations, a researcher ought to use interrelated firms rather than one organizational form.

**Identifying interrelated industries.** To identify interrelated firms in wind and solar energy I triangulate using three types of information. First, for contextual understanding I interviewed public service commissioners and professionals in renewable energy. Second, I used industry reports explaining essential inputs for wind and solar energy industries (Awea, 2002; U.S. Photovoltaic Industry Roadmap Steering Committee, 2003). Third, I identified all components for wind and solar energy systems using Renewable Energy Policy Project reports on Wind and PV manufacturing requirements (Sterzinger & Svrcek, 2004, 2005). Then, using counts of component and system manufacturers and a modification of the commonly used Location Quotient (McCann, 2001), I calculate an interrelated agglomeration quotient to represent clustering.

**Identifying interrelated agglomeration concentrations.** The measure for interrelated agglomeration concentrations is an extension of the Location Quotient (LQ), the most frequently used measure of agglomeration (O'Donoghue & Gleave, 2004). LQ is a ratio of a percentage of people employed in the industry for an identified region over the percentage employment in the industry for a nation. It can be represented by

$$LQ = \frac{e_i}{E_i} \tag{4.0}$$

Where:

i = industry
$e_i$ = regional employment
$E_i$ = national employment

The next three paragraphs explain how I modify the LQ to better suit this study's representation of clusters as *interrelated* firms.

In application to this study, LQ suffers from two limitations. First, it does not account for possible skewing from a few large firms versus many small firms since it only measures employment, and second, it does not account for agglomeration of interrelated firms. To overcome the first limitation, this study measures the number of firms in a region rather than percentage employment. A commonly used measure to treat for industry concentration is the Herfindahl index. However, a Herfindahl index uses a sum of squares of each firm's market share to represent industry structures that range from perfect competition (values near zero) to perfect monopoly (value of 10,000). Other information such as employment share can be used. Unfortunately, market share, employment share, or other similar type information is not available for wind and solar manufacturers.

An additional difficulty in using employment level datum is a potential selection problem, since skilled labor pools are an essential factor condition for clusters. Firm count is a better metric for three reasons: 1) as stated before, large employers could misrepresent clustering, 2) many researchers hypothesize the greater concentrations of smaller firms leads to more positive externalities (McCann, 2001; Rosenthal & Strange, 2007; Saxenian, 1994), and 3) data on wind and solar system and component manufactures is limited to counts.

Using firm counts rather than employment, changes the Location Quotient, equation 4.0, to a Firm Location Quotient (FLQ) for a designated geographic region. It can be represented by equation 4.1.

$$FLQ_i = \frac{f_i}{F_i} \tag{4.1}$$

Where:
- i = industry
- $f_i$ = number of firms in region
- $F_i$ = number of firms in nation

To overcome the second limitation of measuring concentrations of just one industry in a geographic region, geographic concentrations of interrelated firms are summed as well. The summation of firm count ratios for each identified interrelated industry creates an Interrelated Location Quotient (ILQ) for each identified geographic region. ILQ is the dependent variable for this study. It can be represented by equation 4.2.

$$ILQ_m = \sum_{i=1}^{I} \frac{f_{im}}{F_i} \tag{4.2}$$

Where:
- m = geographic region
- i = industry
- I = all identified interrelated industries
- $f_i$ = number of firms in region
- $F_i$ = number of firms in nation

Solar and wind manufacturing clusters are comprised of very different firms and component suppliers. The ILQ for solar energy manufacturing clusters is different than the ILQ for wind energy manufacturing clusters. Each MSA has an ILQ for solar manufacturing clustering and a different ILQ for wind manufacturing clustering.

**Data sources for dependent variable.** The data source for firm counts is the marketing journal *Thomas' Register of American Manufacturers*. Published annually since 1905, the Thomas Register is a well-known and commonly used source for information on American manufacturers. For example, Klepper and Simons (2000) used the Thomas Register for their study of the evolution of the radio and television receiver industry. For the ILQ, type of manufacturer, location of manufacturer, and annual counts by type and location come from listings in the Thomas Register.

I examined Thomas Register indexes for Volumes 1978 - 1995 to identify all possible product categories representing components and systems for wind and solar/PV energy systems. A listing of Thomas Register product categories tracked is located in Appendix C. Not included in the solar counts were sales firms, firms that only install energy systems, or those focusing on solar water or house heating. The focus for solar and PV energy is production of electricity, not passive heating. Not included in the wind counts were firms that distributed and sold windmills, or installed and repaired windmills, unless, of course, they were part of the manufacturing firm. The windmill category in the Thomas Register listed two manufacturers of ornamental windmills (Aero Manufacturing of Geneva, Nebraska, and Air Electric Machine of Lohrville, Iowa) that were eliminated from the data set. Some firms manufactured entire systems and components, or manufactured more than one type of component. In order to avoid double counting these firms, binary categories tracked categories of components and system. Firms that provide raw materials such as silicon were not counted because it was impossible to distinguish those firms that provide inputs for these industries specifically versus those who do not.

The listings in the Thomas Register were verified against multiple listings of manufacturers published over the time span of the study. They include: 1977 Solar Industry Index produced by Solar Energy Industries Association (SEIA), 1983 American Wind Energy Association Directory of Manufacturers, 1988 SEIA PV guide, 1993 Interstate Renewable Energy Council Guide to Renewable Systems, 1984 Department of Energy PV Guide, and lists of respondent firms for the Department of Energy's Annual Solar Thermal collector and Photovoltaic Module Manufacturers Survey. When there were discrepancies, such as if a manufacturer was listed in one of the guides used for cross-reference but did not show up in the Thomas Register, it was eliminated from the count.

Next I explain the data sources and operationalization of the explanatory variables and the control variables. All explanatory variables are centered and lagged. All control variables are lagged except for incentives, which influence the years they are in effect.

## Explanatory Variables

**Congruous institutional logics.** Institutional logics that are congruous for wind and solar energy manufacturing clusters can occur in regions where human populations have a pro-environmental ideology (Mitchell et al., 1992; Sine & Lee, 2009). This study represents the pro-environmental institutional logic of a population with a pattern of congressional representatives voting in a pro-environmental manner. These data are available from the *National Environmental Scorecard* published annually by the League of Conservation Voters (LCV). The *Environmental Scorecard* reports the votes of US

Congress members on about 15 bills that are selected for having pro-environmental and anti-environmental positions. An absence counts as an incorrect vote. The LCV provides a score for each Representative and Senator as a percentage of pro-environmental votes, such that scores run from 0 to 100, with higher scores indicating a more instances of pro-environmental voting behavior.

This analysis uses House of Representative voting patterns rather than Senate voting patterns for two reasons. First, LCV scores differ between the two chambers of Congress for any given year because of different roll-call votes (Groseclose et al., 1999). To maintain consistency, this analysis uses only votes from Representatives rather than Senators. Second, Representative are more 'representative' of their populace in a particular region, because the number of Representatives in Congress increases with a state's population. Each state has two Senators, regardless of its population; as such they represent the state's interests overall and not those of particular MSAs. Several researchers have used LCV scoring of Representatives to capture the characteristics of voters and their support for environmental issues (Levitt, 1996; Nelson, 2002). Since a state may have multiple MSAs, using averaged Senate votes creates a pro-environmental measure for the state, rather than a particular MSA. By using Representative votes, a finer measure for MSA pro-environmental institutional logic is possible.

In order to represent the core of a MSA, the Representative districts that comprise an MSA are used to create an average LCV score. For example, since St. Louis is in Missouri and Illinois, all identified Representative's districts were used, regardless of which state they were in. All district identifications came out of Congressional

Quarterly's publications: Districts in the 1970s, Congressional Districts in the 1980s, and Congressional Districts in the 1990s.

**Pecuniary externalities.** Pecuniary externalities result from benefits achieved through usual market interactions, where a positive externality results in reduced prices for an input (Scitovsky, 1957). Economic geographers often study this type of externality in their research. For this model, pecuniary externalities are represented by the presence of a skilled labor pool essential to wind and solar energy projects (Audia et al., 2006; Audretsch & Feldman, 1996; Boschma & Wenting, 2007; Sine & Lee, 2009). Sine and Lee (2005) constructed a measure for human capital for wind energy projects for the number of people in each state employed in technical fields relevant to wind energy. They used the SIC and NAICS codes to compile the employment in the industry groups of Engine and Turbines, Electric Transmission and Distribution Equipment, Electronic Components and Accessories, Miscellaneous Electrical Machinery, and Aircraft Parts.

The Renewable Energy Policy Project (Sterzinger & Svrcek, 2004), identified the relevant skills for wind manufacturing as SIC codes: 335103-Engines And Turbines, 336103-Electric Distribution Equipment, 336703-Electronic Components And Accessories, 336903-Miscellaneous Electrical Equipment & Supplies, and 337203-Aircraft And Parts. For solar and photovoltaic manufacturing (Sterzinger & Svrcek, 2005; US Photovoltaic Industry Roadmap Steering Committee, 2003), the relevant skills are SIC codes: 336103-Electric Distribution Equipment, 336703-Electronic Components And Accessories, 336903-Miscelaneous Electrical Equipment & Supplies, 336709-Other Electronic Components & Accessories, 336744-Semiconductors And Related Devices, 338203-Measuring And Controlling Devices, and 332103-Flat Glass. This data came from the Bureau of Labor Statistics' Covered Employment and Wages Program. Although SICs contain six digits, data for MSAs was available for the first three digits of SICs. To scale this data, skilled labor is a ratio of employment in designated areas divided by total manufacturing employment in a MSA.

A pecuniary externalities and institutional logic interaction term is necessary since hypothesis 2a predicts a *moderating* relationship between a congruous institutional logic and pecuniary externalities on levels of clustering. The institutional logic variable, LCV scores, and the pecuniary externalities variable, skilled labor ratio, are lagged and centered. The presence of these variables twice in the model creates multicollinearity problems. By centering the explanatory variables, the collinearity resulting from interaction variables is reduced (Aiken & West, 1991).

**Technological externalities.** Technological externalities impact the production function, but the benefits result from nonmarket interactions (Scitovsky, 1957). This type of externality is often captured in organizational theory research as knowledge spillover. Research in the biotechnology industry identifies knowledge spillover as an essential mechanism for firm clustering (Owen-Smith & Powell, 2004). For this model, technological externalities are represented by the potential knowledge spillover from the underlying science that is developed in related university departments (Owen-Smith & Powell, 2004; Stuart & Sorenson, 2003a). Several researchers have shown that the geographic limits of knowledge spillover is approximately a 100-mile radius (e.g. Jaffe et al., 1993). As such, only universities located in MSAs or consolidated metropolitan statistical areas (CMSA) are considered to be a source of knowledge spillover in the urban area.

The explanatory variable for knowledge spillover is measured by the total annual research spending by all universities in each MSA in the relevant engineering disciplines for wind and solar energy. This data comes from the National Science Foundation as part of its WebCASPAR Integrated Science and Engineering Resource Data System. Relevant engineering disciplines for wind energy are aerospace, electrical, and mechanical; for solar, they are chemical, electrical, and mechanical (Fasulo & Walker, 2007). The total number of universities and colleges with any reported spending in the relevant disciplines between 1978 and 1995 is 330.

A technological externalities and institutional logic interaction term is necessary since hypothesis 2b predicts a *moderating* relationship between a congruous institutional logic and technological externalities on levels of clustering. The institutional logic variable, LCV scores, and the technological externalities variable (university research spending), are lagged and centered.

Another important source of knowledge spillover for renewable energy manufacturing are the three national laboratories. They are: 1) National Renewable Energy Laboratory (NREL), started in 1977 in Boulder, Colorado, (NREL, 2009), 2) Sandia National Laboratories, started in 1949 in Albuquerque, New Mexico, (Sandia National Laboratories, 2009), and 3) Lawrence Berkeley National Laboratory, started in 1931 in Berkeley, California (Lawrence Berkeley National Laboratory, 2009). They are represented with an indicator variable in the data set for these three MSAs.

## Control Variables

**Demand conditions.** Demand conditions are synonymous with informed and discerning consumers, they are represented by alternative energy generation projects. Previous researchers (Russo, 2001; Sine et al., 2005) have studied wind energy projects. This study builds on their research by including solar energy projects as well as wind energy projects in the sample and uses them as informed customers, modeled by Porter as demand conditions. The data set includes wind and solar qualifying facilities but not hydroelectric dams, landfill gas collection, or geothermal heat sources. Similar to the measure used as a dependent variable by Russo (2001; 2003) and Sine and colleagues (Lee & Sine, 2005; Sine et al., 2005), I use Federal Energy Regulatory Commission (FERC) filings to track wind and solar qualifying facilities. Filings for 1978-1995 come from FERC's Qualifying Facilities Report (US Federal Energy Regulatory Commission, 1995).

**Factor conditions.** Factor conditions represent a cluster's economic environment. All factor condition variables have been used by previous researchers with similar contexts (Lee & Sine, 2005; Russo, 2001, 2003; Sine & Lee, 2009), which improves this study's construct validity (Hoyle et al., 2002). The study controls for interest rates, per capita gross state product, and gross domestic product. These data are available from the Federal Reserve and the US Bureau of Economic Analysis. State values for average electricity prices came from the Department of Energy's Energy Information Administration. If a MSA crossed state lines, the prices for the states were averaged. Additionally, MSA population, from Global Insight, is used to control for MSA size. All control variables are lagged with the exception of incentives.

Regulatory incentives are represented by counts of incentives for wind and solar applicable to each MSA. This is similar to a measure used by Lee and Sine (2005) and Sine and Lee (2009). Although avoided cost (the price paid by each utility to generators) would be a more exact measure (Russo, 2001, 2003), all states do not have complete records on avoided costs paid to qualifying facilities. An indicator variable is used for years in which the federal incentives were enacted (Russo, 2001, 2003). State incentives were identified through listings in the *Solar Law Reporter*, and then cross-referenced with 1982 Summary of State Financial Incentives for Renewable Energy produced by the National Conference of State Legislatures, 1985 Solar Rating & Certification State Solar Directory, and 1997 Interstate Renewable Energy Council's Survey of Renewable Energy Incentives.

Natural resource potential for wind and solar energy are represented in the model by multiplying the solar or wind rating times the area in kilometers squared. Following Russo's (2003) delimitations between high wind potential at classes 6 and 7, and lesser wind potential at classes 1 through 5, this study uses a similar High Wind Energy Potential variable except I set the high wind energy potential threshold at Class 4 and above (Department of Energy, 2000). Wind Class 4 is still more conservative than a previous study by Pacific Northwest Laboratories which set the threshold at Class 3 (1991). A similar variable for high solar energy potential is created for comparative analysis using a high solar energy potential annual threshold of 5,000 $Wh/m^2/day$ and above. The data was downloaded through a geographic information system (GIS) that provides a 40-km resolution level of data at http://www.nrel.gov/gis/. The National Renewable Energy Laboratory's (NREL) energy potential information was matched with the ESRI GIS software sample data provided by ArcMap to calculate energy potential times kilometers$^2$ per state. If a MSA crossed state lines such as in St. Louis, its potential was an average of that for the states in which it is located, in this case, Illinois and Missouri.

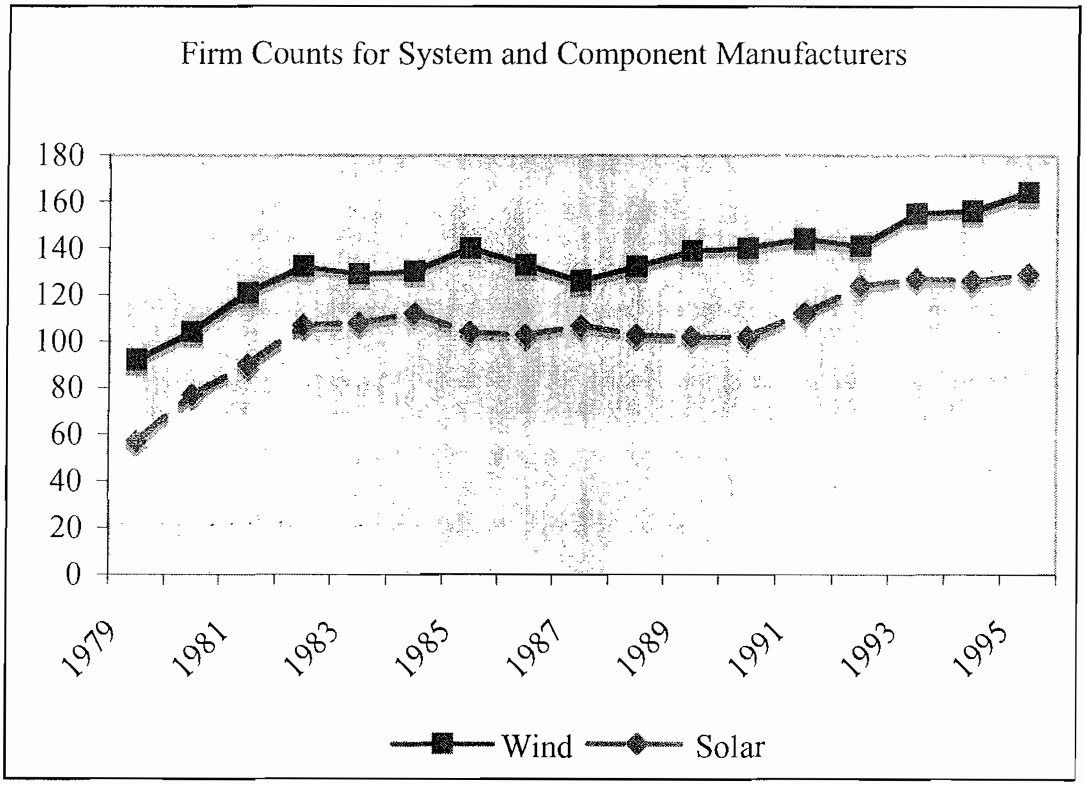
Up to this point in the chapter I have discussed the empirical setting, sample frame, sample design, and operationalization of the variables. In the next section I explain the specification of fixed effects for the panel data and how it is used to test the hypotheses from Chapter 3.

## Statistical Estimation

The statistical estimation method for this study was determined by the nature of the dataset. In order to test causal relationships, the data needed to be longitudinal. In order to test how varying levels of a congruous institutional logic influenced clustering, the data needed to be cross-sectional for many MSAs. The result is a panel data set. Advantages to using panel data are controlling for MSA heterogeneity, more reliable estimates and less collinearity given greater amounts of informative data and the ability to understand adjustments across time (Baglati, 2008).

This particular panel dataset is considered a micro panel because it has a large N of 252, and a relatively short period T (time), since it does not exceed 20 years. Cross-section dependence and non-stationarity is not a concern over this shorter time period (Baglati, 2008). To confirm this I used a Nyblom-Harvey test (Nyblom & Harvey, 2000). The null hypothesis assumes no common trends among the variables. As such it is also a test for cointegration. Failure to reject the null hypothesis indicates stationarity. For both dependent variables, Wind ILQ (p value = 0.87) and Solar ILQ (p value = 0.87) the test failed to reject the null hypothesis of stationarity when a time trend is included in the model. A trend variable is included in the analysis to capture general growth in the dependent variables[2]. As such, time-series analysis was not employed, since it is more appropriate for non-stationarity in the data when a trend variable is included. Figure 6 shows the total annual counts for wind and solar system and component manufacturers listed in the Thomas Register.

**Figure 6.** Annual Counts of Wind and Solar Component and System Manufacturers in Thomas Register




[2] A shift variable was employed for the years the Federal Incentive lapsed, 1986 to 1992, however it was not significant, nor changed any of the estimated coefficients.

A fundamental distinction of panel data models using continuous variables is between fixed effects and random effects (Cameron & Trivedi, 2008). Random effects assumes exogeneity of the regressors on the MSA individual effects, while fixed effects allows for endogeneity of the regressors with the MSA individual effects (Baglati, 2008) The decision between fixed and random effects should be about model selection and not just a Hausman test, in which rejection means using a fixed effects model and non-rejection means using a random effects model (Baglati, 2008). A disadvantage of fixed effects is that time invariant regressors are eliminated from the model.

This dataset is best represented with a fixed effects model, since there are many unobserved characteristics of the metropolitan statistical areas (MSA). Using a fixed effects model allows for endogeneity of the regressors for the individual effects of each MSA (Baglati, 2008). A Hausman test supports the fixed effects specification, indicating that the random effects estimate was significantly different from the unbiased fixed effects estimate (for Wind model $\chi^2(23) = 175.36$; for Solar model $\chi^2(23) = 3601.92$).

Fixed effects estimation begins with a model where $i$ represents each MSA for all $t$ from 1979 to 1995:

$$y_{it} = a_i + \beta_1 x_{it1} + \beta_2 x_{it2} + \ldots + \beta_k x_{itk} + u_{it}. \tag{4.3}$$

The time invariant explanatory variables are represented with $a_i$. For each $i$, in this case MSA, the equation is averaged resulting in:

$$\bar{y}_{it} = a_i + \beta_1 \bar{x}_{it1} + \beta_2 \bar{x}_{it2} + \ldots + \beta_k \bar{x}_{itk} + \bar{u}_{it} \tag{4.4}$$

The data are time-demeaned by subtracting the mean model, equation 4.4, from the original model, equation 4.3, such that:

$$\ddot{y}_{it} = y_{it} - \bar{y}_i \tag{4.5}$$

Since the unobserved effects for each MSA are in both equations, the unobserved effect, $a_i$, is removed:

$$\ddot{y}_{it} = \beta_1 \ddot{x}_{it1} + \beta_2 \ddot{x}_{it2} + \ldots + \beta_k \ddot{x}_{itk} + \ddot{u}_{it} \tag{4.6}$$

The estimation is calculated using pooled ordinary least squares (Wooldridge, 2003).

Given the possible recursive nature of variables influencing incentives for wind and solar technologies and the pro-environmental proclivities of a human population, there is a concern about endogeneity in this dataset. This endogeneity can be treated with instrumental variable estimation. An instrumental variable is another independent variable that should be correlated with the variable for which the instrumental variable is now an alternative estimator and not correlated with the error term for the model (Kennedy, 2003). For this dataset, the variables for which I am concerned about contemporaneous correlation are counts of state wind and solar incentives. The instrument, in other words, the alternative estimator, is the amount of electricity a state imports. Electricity imports is a good instrument because it should be related to a state's policy choices for incentivizing alternative energy generation and energy conservation, but not to the error term for the model. Electricity import information comes from the Energy Information Administration. The Davidson-MacKinnon test for exogeneity using average electricity imports as an instrumental variable for state incentives, indicates the instrumental variable estimation is not necessary (for Wind model $F(1, 3752)=0.0041$, p value=0.9487; for Solar model $F(1, 3752)=0.6812$, p value =0.4092) to correct for endogeneity.

Another concern is non-random sample selection leading to biased coefficient estimators (Wooldridge, 2003). The sampling frame identified all MSAs in the U.S. in 1990—because of missing population data, 24 of those MSAs were excluded from the sample. Using a Heckit method (Hamilton & Nickerson, 2003; Heckman, 1979) this incidental truncation is accounted for by generating a variable, the inverse mills ratio (IMR), from an explicit selection equation (Wooldridge, 2003). If significant, the IMR is then included into the estimation to account for this selection bias. To generate the IMR, a variable not included in the model, must be used in the explicit selection equation. This variable must be related to being excluded from the sample, but not highly correlated to the dependent variable. I use total non-farm labor for this variable, since it is highly related to MSA population and one of the main reasons for exclusion was the cities had not yet reached the MSA population minimum, and not highly correlated to the overall model. If the IMR variable in the overall model is statistically significant, it is a sample selection problem, and the IMR variable should be included in further estimations. Its influence on the interpretation of the estimations must be taken into account in the analysis.

My original model included a measure for wind and solar potential and an indicator variable for national laboratories, since all were formed prior to the timeframe of the dataset. However, since they are time invariant, they drop out of a fixed effects model. Even though fixed effects models eliminate time invariant regressors, a Hausman-Taylor estimator (Hausman & Taylor, 1981) allows for overcoming the absorption of the time invariant regressors into the fixed effects transformation. A Hausman-Taylor instrumental variable estimator allows for the inclusion of time-invariant regressors into a fixed effects specification (Cameron & Trivedi, 2008). The Hausman-Taylor instrumental variable estimator can be calculated using only the information already present in the model by distinguishing variables that are time invariant and not correlated with the error term in the model (Greene, 2003). The variable I identify as uncorrelated with the fixed-effects assigned to MSAs is the 1983 Supreme Court ruling upholding PURPA and avoided cost rates. This is a reasonable assumption since the Supreme Court ruling in support of PURPA is random to specific MSA characteristics. By using a Hausman-Taylor estimator, I am able to assign an estimator to wind and solar potential and the presence of a national laboratory in an MSA.

To test hypotheses 1 and 2, the estimation of the models is sequential, adding in explanatory variables to determine if inclusion of the explanatory regressors supports the hypotheses. The first model includes control variables, the following models build sequentially by adding the institutional alignment variable, then the interaction term for the institutional alignment variable with each pecuniary and technological externality variables.

In order to test hypotheses 3 for a significant difference in influence of institutional logics when technological uncertainty is greater, a t-test between the wind energy clusters model and solar energy clusters model is used. During the time frame of the study, 1979-1995, wind energy had greater commercial viability than solar energy (Gipe, 1995). As discussed in the section on empirical setting, the technological uncertainty was much greater for solar than for wind technology. Given the distinct difference in technological uncertainty between the two technologies, there is an opportunity to test for a significant difference between the explanatory variables when using wind energy manufacturing versus solar energy manufacturing clustering data. Hypothesis 3 predicts that the value of the LCV regression coefficient for wind will be less than for solar because solar has greater technological uncertainty.

The null hypothesis for the t-test sets the coefficient multiplied with the average value of the dependent variable for each model equal to each other.

$$Ho : \bar{y}_{wind} * \beta_{LCVwind} = \bar{y}_{solar} * \beta_{LCVsolar}$$

The t-test uses the each coefficient estimate, standard error, and sample size for the two mean test assuming unequal variance.

In order to determine if the relationship between the explanatory variables and the dependent variable are causal or spurious, I use a Granger causality estimation (Granger, 1969). This examines the influence of the explanatory variable, lagged by one year, on the dependent variable, and then reverses the regression. First, the explanatory variable, lagged one year, is regressed on the dependent variable (the traditional regression estimation) and then the dependent variable, lagged one year, is regressed on the explanatory variable. To further examine a causal relationship, this study focuses on MSAs that had zero clustering at the start of the timeframe, and later did exhibit clustering. Focusing on such MSAs allows me to examine whether the hypotheses hold when a reverse causal relationship is not possible since the level of clustering is zero. In the next chapter, I apply these estimation methods, interpret the results, and determine results for hypotheses testing.

# CHAPTER V

# EMPIRICAL TESTING AND RESULTS

This study seeks to answer the research question: *How do institutions, specifically varying levels of a congruous institutional logic, affect regional cluster emergence?* The previous chapter explained the empirical setting, sampling frame, variables, and estimation methods. This chapter tests the hypothesized relationships between congruous institutional logics, technological uncertainty, and cluster growth. The first section of this chapter presents descriptive statistics, followed by the application of a Heckit method (Heckman, 1979) to correct for sample selection. Then I test the first two hypotheses using a fixed effects estimation. As explained in the previous chapter, fixed effects estimation is preferred in this empirical setting due to the many unobserved characteristics of metropolitan statistical areas (MSAs). Then the third hypothesis is tested with a t-test. Following that, the causal relationship between the variables of interest is examined. Since time-invariant regressors may be important to the model, a Hausman-Taylor estimation is examined. This chapter concludes with a review of the results and a discussion of this study's limitations.

## Data Characteristics

Table 3 provides descriptive statistics for the dependent variables, control variables, and explanatory variables. All explanatory and control variables are lagged one year, with the exception of the Federal Incentive indicator and the count of state Wind and Solar Incentives, because incentives only impact the years in which they are in effect. Several variables are logged to improve their linear relationship with the dependent variables of Wind Interrelated Location Quotient (ILQ) and Solar Interrelated Location Quotient (ILQ. They are: Population, Wind Generating Facilities, Solar Generating Facilities, Wind and Solar Skilled Labor, and All Non-farm Labor. The three explanatory variables of 1) League of Conservation Voter Scores (LCV), 2) LCV interacted with Skilled Labor (LCV X Labor), and 3) LCV interacted with Research and Development (LCV X R&D), exhibit high levels of multicollinearity. To treat the collinearity, each variable that shows up in the model twice is centered (Aiken & West, 1991).

Since the dataset contains cross-sectional data spanning many years, variables were centered by subtracting the mean value for time period $t_i$, from each observed value for the same time period. Centered variables are: Wind Skilled Labor, Solar Skilled Labor, Wind University R&D, Solar University R&D, LCV, LCV X Wind Labor, LCV X Solar Labor, LCV X Wind R&D, and LCV X Solar R&D. With centering, the highest variance inflation factor (VIF) is 2.47 for the variable Percent Change in US GDP. Prior to centering the highest VIF was 8.86 for the interaction variable LCV X Wind Labor. After centering, the mean VIF was 1.49, compared to before centering, where the mean

VIF was 2.69. Table 3 provides descriptive statistics for variables employed in this study.

**Table 3.** Descriptive Statistics

| | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| Wind CLQ (%) | 0.67 | 2.16 | 0.00 | 23.46 |
| Solar/PV CLQ (%) | 0.69 | 3.34 | 0.00 | 49.72 |
| Population (thousands) [a, b] | 5.73 | 1.07 | 4.05 | 9.73 |
| Change State Gross Prod (%) [a] | 0.07 | 0.04 | -0.39 | 0.30 |
| Change US GDP (%) [a] | 0.07 | 0.03 | 0.03 | 0.11 |
| Avg Price of Elec ($/MBtu) [a] | 16.84 | 4.74 | 3.08 | 35.55 |
| Commercial Interest Rate [a] | 10.47 | 3.31 | 6.00 | 18.87 |
| Federal Incentive Indicator | 0.59 | 0.49 | 0.00 | 1.00 |
| Sup Court Ruling Indicator | 0.76 | 0.42 | 0.00 | 1.00 |
| No. Wind Incentives | 1.33 | 1.30 | 0.00 | 6.00 |
| No. Solar Incentives | 1.84 | 1.46 | 0.00 | 6.00 |
| Trend | 10.00 | 4.90 | 2.00 | 18.00 |
| Wind Generating Facilities [a, b] | 0.13 | 0.52 | 0.00 | 5.28 |
| Solar Generating Facilities [a, b] | 0.03 | 0.22 | 0.00 | 3.00 |
| Wind Labor (thousands) [a, b, c] | 0.03 | 1.80 | -4.06 | 2.80 |
| Solar Labor (thousands) [a, b, c] | 0.02 | 1.52 | -3.56 | 2.81 |
| Wind R&D ($ Millions) [a, b, c] | 0.01 | 3.81 | -3.49 | 8.83 |
| Solar R&D ($ Millions) [a, b, c] | 0.01 | 3.89 | -3.61 | 8.67 |
| Wind Potential ($km^2$) [b] | 7.44 | 4.45 | 0.00 | 12.35 |
| Solar Potential ($km^2$) [b] | 6.52 | 5.74 | 0.00 | 13.20 |
| National Laboratory Indicator | 0.01 | 0.10 | 0.00 | 1.00 |
| LCV (/100) [a, c] | 0.00 | 0.25 | -0.51 | 0.66 |
| LCV X Wind Labor [a, b, c] | -0.02 | 0.44 | -2.48 | 1.97 |
| LCV X Solar Labor [a, b, c] | -0.01 | 0.38 | -2.17 | 1.76 |
| LCV X Wind R&D [a, b, c] | 0.16 | 0.95 | -3.61 | 4.35 |
| LCV X Solar R&D [a, b, c] | 0.16 | 0.97 | -3.30 | 4.35 |

[a] lagged; [b] logged; [c] centered

Table 4 provides correlations for variables used in the wind energy manufacturing cluster model, and Table 5 provides correlations for the variables used in the solar energy manufacturing cluster model. In these tables, superscripts indicate which variables are lagged ([a]), logged ([b]), and centered ([c]). Correlations greater than 0.8 indicate high collinearity between the variables (Kennedy, 2003). After centering, none of the variables have correlations higher than 0.8, thus reducing concerns about collinearity

A few correlations are worth noting. Both wind clustering (Wind ILQ) and solar clustering (Solar ILQ) increase with population. This is not surprising since total numbers of firms generally increase with population. Although fairly small, 0.08 for Wind ILQ and 0.07 for Solar ILQ, the number of incentives is significantly correlated with clustering as would be expected.

Wind research and development (R&D) and solar R&D spending in universities is significantly correlated with clustering. A greater correlation is between wind and solar R&D and MSA population. Since larger cities tend to have more universities, this is not surprising. Wind potential is positively correlated with the number or wind incentives. Likewise, solar potential is positively correlated with the number of solar incentives. It appears that legislatures are more likely to incentivize renewable energy that they have the potential to generate in their states. The explanatory variable, League of Conservation Voters' scores (LCV), is significantly correlated with the clustering variables, Wind ILQ and Solar ILQ.

## Table 4. Correlations for Wind Energy Manufacturing Clustering

| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | Wind ILQ (%) | | | | | | | | | | | | | | | | | |
| (2) | Population (thousands) [a,b] | **0.54** | | | | | | | | | | | | | | | | |
| (3) | Change State Gross Prod (%) [a] | 0.01 | -0.00 | | | | | | | | | | | | | | | |
| (4) | Change US GDP (%) [a] | 0.01 | **-0.04** | 0.67 | | | | | | | | | | | | | | |
| (5) | Avg Price of Elec ($/MBtu) [a] | **0.13** | **0.16** | **-0.33** | **-0.47** | | | | | | | | | | | | | |
| (6) | Commercial Interest Rate [a] | 0.01 | **-0.03** | **0.33** | **0.53** | **-0.39** | | | | | | | | | | | | |
| (7) | Federal Incentive Indicator | 0.00 | -0.01 | **0.33** | **0.43** | **-0.30** | **0.30** | | | | | | | | | | | |
| (8) | Sup Court Ruling Indicator | -0.00 | **0.04** | **-0.52** | **-0.72** | **0.63** | **-0.58** | **-0.46** | | | | | | | | | | |
| (9) | No. Wind Incentives | **0.08** | 0.01 | **-0.03** | 0.02 | -0.01 | **0.10** | **0.04** | 0.01 | | | | | | | | | |
| (10) | Trend | -0.01 | **0.05** | **-0.45** | **-0.72** | **0.58** | **-0.70** | **-0.34** | 0.74 | **-0.05** | | | | | | | | |
| (11) | Wind Generating Facilities [a,b] | **0.32** | **0.30** | **-0.11** | **-0.11** | **0.19** | **-0.14** | **-0.09** | **0.12** | **0.13** | **0.15** | | | | | | | |
| (12) | Wind Labor (thousands) [a,b,c] | 0.01 | **-0.05** | 0.02 | 0.00 | 0.02 | -0.00 | -0.00 | 0.00 | **-0.06** | 0.00 | **0.16** | | | | | | |
| (13) | Wind R&D ($ Millions) [a,b,c] | **0.39** | **0.60** | 0.02 | -0.00 | **0.13** | -0.00 | -0.00 | 0.00 | **0.08** | 0.00 | **0.21** | **-0.03** | | | | | |
| (14) | Wind Potential ($km^2$) [b] | **0.12** | 0.01 | 0.01 | -0.00 | -0.02 | 0.00 | 0.00 | -0.00 | **0.38** | 0.00 | **0.14** | **-0.09** | **0.07** | | | | |
| (15) | Nation Lab Indicator | **0.25** | **0.18** | 0.02 | -0.00 | **0.04** | 0.00 | 0.00 | 0.00 | 0.02 | -0.00 | **0.26** | 0.02 | **0.17** | **0.09** | | | |
| (16) | LCV (/100) [a,c] | **0.24** | **0.24** | -0.02 | 0.00 | **0.12** | -0.00 | -0.00 | -0.00 | **0.16** | 0.00 | **0.04** | **-0.04** | **0.17** | **0.09** | **0.04** | | |
| (17) | LCV X Wind Labor [a,b,c] | 0.02 | **-0.05** | 0.02 | **0.03** | **-0.08** | **0.03** | **0.03** | **-0.05** | **0.07** | **-0.04** | 0.02 | **0.14** | -0.02 | -0.00 | 0.08 | 0.07 | |
| (18) | LCV X Wind R&D [a,b,c] | **0.31** | **0.21** | -0.01 | 0.00 | **0.12** | -0.01 | 0.01 | -0.01 | **0.06** | 0.01 | **0.07** | -0.02 | **0.13** | 0.00 | **0.08** | 0.07 | -0.01 |

Significance greater than 10% indicated with bold typeface

**Table 5.** Correlations for Solar Energy Manufacturing Clustering

| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) | (16) | (17) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | Solar ILQ (%) | | | | | | | | | | | | | | | | | |
| (2) | Population (thousands) [a, b] | **0.46** | | | | | | | | | | | | | | | | |
| (3) | Change State Gross Prod (%) [a] | 0.01 | -0.00 | | | | | | | | | | | | | | | |
| (4) | Change US GDP (%) [a] | 0.00 | **-0.04** | **0.67** | | | | | | | | | | | | | | |
| (5) | Avg Price of Elec ($/MBtu) [a] | **0.12** | **0.16** | -0.33 | **-0.47** | | | | | | | | | | | | | |
| (6) | Commercial Interest Rate [a] | 0.00 | **-0.03** | 0.33 | **0.53** | **-0.39** | | | | | | | | | | | | |
| (7) | Federal Incentive Indicator | 0.00 | -0.01 | 0.33 | **0.43** | **-0.30** | 0.30 | | | | | | | | | | | |
| (8) | Sup Court Ruling Indicator | -0.00 | **0.04** | **-0.52** | **-0.72** | 0.63 | **-0.58** | **-0.46** | | | | | | | | | | |
| (9) | No. Solar Incentives | **0.07** | 0.03 | 0.07 | **0.10** | 0.02 | 0.20 | **0.10** | **-0.08** | | | | | | | | | |
| (10) | Trend | -0.00 | **0.05** | **-0.45** | **-0.72** | **0.58** | **-0.70** | -0.34 | 0.74 | **-0.16** | | | | | | | | |
| (11) | Solar Generating Facilities [a, b] | 0.31 | 0.23 | **-0.03** | **-0.06** | **0.14** | **-0.08** | **-0.05** | **0.06** | **0.07** | **0.10** | | | | | | | |
| (12) | Solar Labor (thousands) [a, b, c] | **0.04** | **0.03** | **0.05** | -0.00 | **0.06** | -0.00 | -0.00 | 0.00 | **0.19** | 0.00 | **0.13** | | | | | | |
| (13) | Solar R&D ($ Millions) [a, b, c] | **0.32** | **0.60** | 0.02 | -0.00 | **0.13** | -0.00 | -0.00 | 0.00 | **0.08** | 0.00 | **0.16** | 0.01 | | | | | |
| (14) | Solar Potential ($km^2$) [b] | **-0.03** | **-0.04** | **0.12** | -0.00 | **-0.12** | -0.00 | 0.00 | -0.00 | **0.21** | 0.00 | **0.14** | **0.24** | **-0.03** | | | | |
| (15) | Nation Lab Indicator | **0.17** | **0.18** | 0.02 | -0.00 | **0.04** | 0.00 | 0.00 | 0.00 | **0.08** | -0.00 | **0.11** | **0.05** | **0.17** | **0.11** | | | |
| (16) | LCV (/100) [a, c] | **0.15** | **0.24** | -0.02 | 0.00 | **0.12** | -0.00 | -0.00 | -0.00 | **0.07** | 0.00 | 0.00 | **-0.04** | **0.16** | **-0.26** | **0.04** | | |
| (17) | LCV X Solar Labor [a, b, c] | **0.25** | **0.20** | -0.01 | 0.00 | **0.12** | **-0.01** | 0.01 | **-0.01** | **0.07** | 0.01 | 0.01 | -0.01 | **0.12** | **-0.05** | **0.07** | **0.07** | |
| (18) | LCV X Solar R&D [a, b, c] | **0.03** | **-0.03** | 0.01 | **0.03** | **-0.09** | **0.03** | **0.03** | **-0.05** | **0.06** | **-0.04** | **0.05** | **0.16** | -0.01 | 0.01 | **0.11** | 0.07 | 0.04 |

Significance greater than 10% indicated with bold typeface

Sample Selection Correction and Fixed Effects Estimation

As explained in the previous chapter, 24 metropolitan statistical areas (MSAs) were omitted from the dataset because their annual population data was unavailable from Global Insight and Statistical Abstracts of the United States. I use a Heckit method (Hamilton & Nickerson, 2003; Heckman, 1979) to test and correct potential sample selection bias. I use the logged value of Total Non-farm Labor in the explicit selection equation (Wooldridge, 2003) to generate the inverse mills ratio (IMR). Then, the IMR is included in the full model estimation. Total Non-farm Labor is an appropriate variable to use in the selection model, firstly, because it is not used in the primary model. Secondly, it is correlated with the reason for exclusion from the dataset but not with the dependent variable's errors in the primary model (Wooldridge, 2003).

If the coefficient on the IMR variable is significant, then sample selection bias is a concern (Wooldridge, 2003). Since the IMR variable is not significant in the wind models, sample selection is not a concern for wind manufacturing clusters. However, the IMR in the solar models is positive and significant, indicating a selection bias in the MSAs that were omitted from the sample. The positive sign on the IMR coefficient in the solar models indicates that there are unobserved characteristics in the omitted MSAs that increases the levels of clustering reported. It is impossible to know what these unobserved characteristics might be. The IMR is included in the regressions to correct for this bias. Since the IMR variable must be included in the solar model, it is also included in the wind models for symmetry.

As explained in the previous chapter, fixed effects is the appropriate model for this empirical setting, particularly because MSAs have many unobserved characteristics that influence the type of businesses that form and the propensity for clustering. The fixed effects estimations, including the inverse mills ratio (IMR) variable, are in Table 6 for wind models and Table 7 for solar models. The base model for wind energy manufacturing clusters is column W1, for solar energy manufacturing clusters is column S1.

**Table 6.** Fixed Effects Estimation for Wind Model

| DV - Wind ILQ | W1 | W2 | W3 | W4 |
|---|---|---|---|---|
| Population (thousands) [a, b] | 0.127 | 0.103 | 0.093 | 0.102 |
| | (0.221) | (0.221) | (0.220) | (0.221) |
| Inverse Mills Ratio | 0.609 | 0.605 | 0.605 | 0.608 |
| | (0.380) | (0.379) | (0.379) | (0.380) |
| Change State Gross Prod (%) [a] | -0.395 | -0.374 | -0.384 | -0.366 |
| | (0.470) | (0.472) | (0.471) | (0.475) |
| Change US GDP (%) [a] | 1.560 | 1.531 | 1.538 | 1.525 |
| | (1.007) | (1.008) | (1.009) | (1.010) |
| Avg Price of Elec ($/MBtu) [a] | -0.041** | -0.041** | -0.042** | -0.041** |
| | (0.016) | (0.016) | (0.016) | (0.016) |
| Commercial Interest Rate [a] | -0.008 | -0.008 | -0.008 | -0.008 |
| | (0.008) | (0.008) | (0.008) | (0.008) |
| Federal Incentive Indicator | -0.061** | -0.060** | -0.060** | -0.060** |
| | (0.027) | (0.027) | (0.027) | (0.027) |
| Sup Court Ruling Indicator | 0.142 | 0.143 | 0.145 | 0.145 |
| | (0.103) | (0.103) | (0.103) | (0.103) |
| No. Wind Incentives | 0.060* | 0.058* | 0.058* | 0.058* |
| | (0.034) | (0.034) | (0.034) | (0.034) |
| Trend | 0.014** | 0.014** | 0.014** | 0.014** |
| | (0.007) | (0.007) | (0.007) | (0.007) |
| Wind Generating Facilities [a, b] | -0.359** | -0.356** | -0.356** | -0.356** |
| | (0.158) | (0.158) | (0.158) | (0.158) |
| Wind Labor [a, b, c] | 0.077** | 0.075** | 0.074** | 0.075** |
| | (0.037) | (0.037) | (0.038) | (0.037) |
| Wind R&D [a, b, c] | 0.014 | 0.015 | 0.015 | 0.015 |
| | (0.010) | (0.010) | (0.010) | (0.010) |
| LCV (/100) [a, c] | | 0.114* | 0.116* | 0.122* |
| | | (0.065) | (0.065) | (0.072) |
| LCV X Wind Labor [a, b, c] | | | -0.028 | |
| | | | (0.033) | |
| LCV X Wind R&D [a, b, c] | | | | 0.012 |
| | | | | (0.022) |
| Observations | 4029 | 4029 | 4029 | 4029 |
| MSAs | 252 | 252 | 252 | 252 |
| R-squared | 0.030 | 0.031 | 0.031 | 0.031 |
| F statistic | | 4.14** | 2.083 | 2.083 |

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

[a] lagged; [b] logged; [c] centered

**Table 7.** Fixed Effects Estimation for Solar Model

| DV - Solar ILQ | S1 | S2 | S3 | S4 |
|---|---|---|---|---|
| Population (thousands) [a, b] | 0.763** | 0.724** | 0.759** | 0.713** |
| | (0.305) | (0.309) | (0.309) | (0.309) |
| Inverse Mills Ratio | 1.315*** | 1.319*** | 1.311** | 1.363*** |
| | (0.510) | (0.509) | (0.510) | (0.516) |
| Change State Gross Prod (%) [a] | 2.128*** | 2.167*** | 2.185*** | 2.246*** |
| | (0.606) | (0.607) | (0.608) | (0.613) |
| Change US GDP (%) [a] | -2.077 | -2.142 | -2.149 | -2.226 |
| | (1.447) | (1.451) | (1.451) | (1.456) |
| Avg Price of Elec ($/MBtu) [a] | 0.014 | 0.015 | 0.016 | 0.014 |
| | (0.023) | (0.023) | (0.023) | (0.023) |
| Commercial Interest Rate [a] | -0.012 | -0.012 | -0.012 | -0.012 |
| | (0.011) | (0.011) | (0.011) | (0.011) |
| Federal Incentive Indicator | -0.074** | -0.073** | -0.073** | -0.073** |
| | (0.036) | (0.036) | (0.036) | (0.036) |
| Sup Court Ruling Indicator | -0.122 | -0.125 | -0.129 | -0.114 |
| | (0.146) | (0.146) | (0.146) | (0.144) |
| No. Solar Incentives | 0.098*** | 0.095*** | 0.095*** | 0.094*** |
| | (0.032) | (0.032) | (0.032) | (0.032) |
| Trend | -0.011 | -0.011 | -0.012 | -0.012 |
| | (0.009) | (0.009) | (0.009) | (0.009) |
| Solar Generating Facilities [a, b] | -1.452** | -1.460** | -1.467** | -1.479** |
| | (0.658) | (0.658) | (0.658) | (0.658) |
| Solar Labor [a, b, c] | -0.069 | -0.075 | -0.068 | -0.093 |
| | (0.085) | (0.085) | (0.085) | (0.085) |
| Solar R&D [a, b, c] | 0.010 | 0.011 | 0.011 | 0.012 |
| | (0.016) | (0.016) | (0.016) | (0.016) |
| LCV (/100) [a, c] | | 0.173* | 0.168* | 0.236** |
| | | (0.090) | (0.090) | (0.115) |
| LCV X Solar Labor [a, b, c] | | | 0.083* | |
| | | | (0.042) | |
| LCV X Solar R&D [a, b, c] | | | | 0.088** |
| | | | | (0.041) |
| Observations | 4029 | 4029 | 4029 | 4029 |
| MSAs | 252 | 252 | 252 | 252 |
| R-squared | 0.036 | 0.036 | 0.037 | 0.039 |
| F statistic | | 2.92 | 2.083 | 6.265*** |

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

[a] lagged; [b] logged; [c] centered

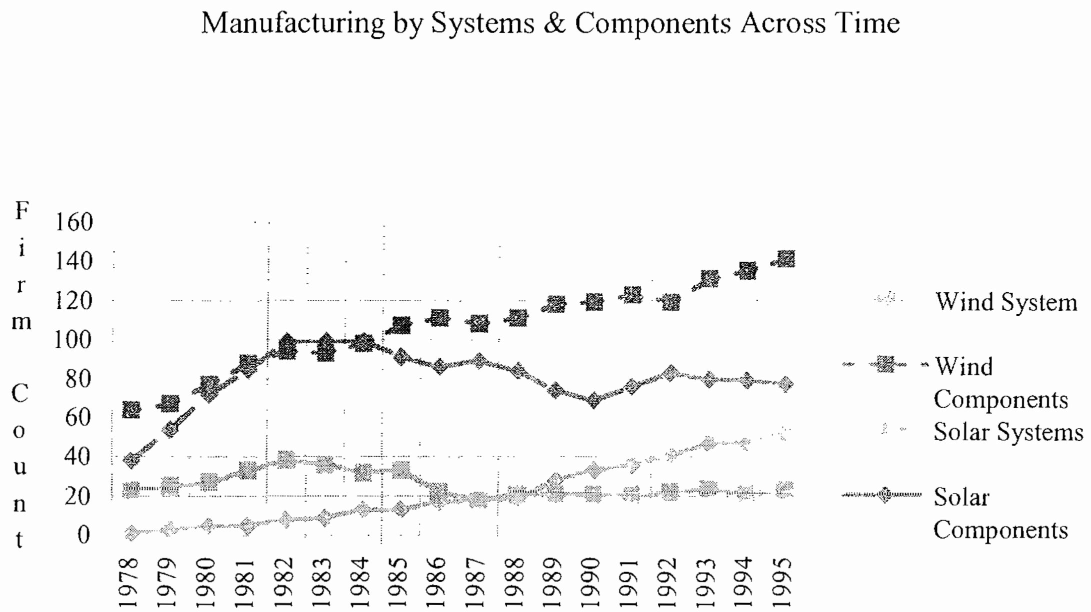
I discuss each variable from the top of Tables 6 and 7 proceeding downward. The estimated coefficient on the Population variable is positive as expected, but it is only significant for the solar model. I expect manufacturing clustering to increase as population of the MSA increases, because number of firms increases with population. The inverse mills ratio coefficient is positive and significant in the solar model, which indicates a selection bias resulting in higher values of the dependent variable.

While most of the explanatory variables have the expected sign, a few variables had opposite signs for the different technologies of wind and solar. Change in State Gross Product is negative for wind models and positive and significant for the solar models. I expect manufacturing to increase when the change in state gross product increases. The surprisingly negative sign for the wind models can be ignored for practical purposes. Not only is it non-significant, the coefficient and the t-values are small (Wooldridge, 2003), ranging from -0.56 to -0.67 across the models. Change in US GDP is positive for wind models and negative for solar models. I expect manufacturing to increase when the change in US GDP is positive as the result of a growing economy. This time, the surprising negative values for the coefficient are in the solar models. It is interesting to note that the signs reverse in each model, but these variables are insignificant.

In the wind models, the negative and significant signs on the Average Price of Electricity coefficients are expected, since manufacturing decreases as the cost of inputs increases. The solar models have a positive sign, however the t-values are small, ranging from 0.59 to 0.63, so once again these can be ignored for practical purposes. The negative signs on Commercial Interest Rate coefficients are expected since investment in manufacturing is expected to decrease as the cost of capital increases. For both of the models these variables are significant.

The negative and significant coefficients on the indicator variable for the years Federal Incentives were enacted are surprising. Previous research (Russo, 2001, 2003; Sine et al., 2005; Sine & Lee, 2009), showed that federal incentives were positively correlated with foundings of wind energy generating facilities. However, previous researchers were measuring founding of qualifying facilities—the customers of the wind manufacturing clusters— not founding of wind energy system and component manufacturers. The only explanation I can see is that the rise in component manufacturers disguises the drop in system manufacturers during the years the federal incentive was not in effect. In Figure 7, the component and system manufacturer counts that go into the creation of ILQ are shown. Since the dependent variable is measuring interrelated industry *clustering*, the variable does not behave as it did in models for energy generator foundings.

**Figure 7.** Wind and Solar System and Component Manufacturer Counts from 1978-1995




Continuing with the discussion of control variables in the model, the Supreme Court Ruling variable is one for 1983 and later to represent the time period after the Supreme Court supported PURPA's required payment of avoided cost rates by utilities to qualifying facility (QF) energy producers. The Supreme Court Ruling variable was found to be positive and significant in providing legitimacy to wind energy producers (Sine et al., 2005). In Table 6, for the wind models, the Supreme Court Ruling indicator is positive but not significant. In Table 7, for the solar models, the Supreme Court Ruling coefficient is negative. It may be that the Supreme Court ruling supporting payment of avoided cost rates provided stability to wind energy producers but did not influence solar energy producers because solar technology was still not commercially viable. Or, it could be that the Supreme Court ruling did not change the market opportunities for manufacturers because it was expected to support avoided cost rates. The positive and significant coefficients are expected for Number of Wind Incentives and Number of Solar

Incentives. A trend variable is included to capture the generally increasing nature of the dependent variable, ILQ. The trend variable is positive and significant for the wind models. It is not significant for the solar models.

The variable representing informed customers for wind and solar manufacturing clustering is Generating Facilities. The variable for wind and solar is negative and significant. This is likely an artifact of the unit of analysis. The unit of analysis is MSA— this was selected based on previous cluster research and because manufacturing clustering is a predominantly urban activity. However, wind and solar generating facilities are predominantly located outside urban areas. Although Porter (1990) predicts clustering to accompany increased demand conditions, for the alternative energy generating market, the nature of energy-generating siting requirements, counteracts that prediction.

The variable representing the skilled labor pool for wind manufacturing, Wind Energy Labor Pool, is positive and significant. The variable representing skilled labor pool for solar manufacturing, Solar Energy Labor Pool, is negative and not significant. However for Solar Energy Labor Pool, the coefficient is very small and the t-values are not large, ranging from -0.80 to -1.09, indicating that for practical purposes these can be ignored (Wooldridge, 2003).

The variables representing knowledge spillover, Wind R&D and Solar R&D, are positive but not significant. Researchers studying bio-technology clusters have found knowledge spillover to be an extremely strong influence on clustering (Owen-Smith & Powell, 2004). Perhaps since wind and solar energy manufacturing are technologies that do not require expensive laboratories and specialized tacit knowledge, knowledge spillover is not as important in these industries. In the next section I discuss models 2, 3, and 4 that test hypotheses 1, 2a, and 2b.

Testing Direct Effects of a Congruous Institutional Logic on Clustering

Hypothesis 1 predicts a positive and direct relationship between a congruous institutional logic and clustering. The League of Conservation Voters Environmental Scorecard average scores (LCV) represent the congruous institutional logic for congressional representatives for each MSA. Hypothesis 1 predicts a positive direct effect from LCV on the dependent variable, ILQ. Table 6, shows the addition of LCV to the wind manufacturing cluster model in column W2, and Table 7 shows the addition of the LCV to the solar manufacturing cluster model in column S2. The direct effect of a congruous institutional logic is significant for both models. Hypothesis 1 is supported.

To determine if the inclusion of the LCV variable is an improvement to the previous model, I test to see if it has a nonzero partial effect on the dependent variable. Change in $R^2$ is not the best method to determine if inclusion of a regressor improves the model, because $R^2$ always improves with the inclusion of another variable (Wooldridge, 2003). An F statistic can be used to determine if model W2 is an improvement over W1. The F statistic is calculated using the $R^2$ values for model W1 and W2:

$$F = \frac{(R^2{}_{W2} - R^2{}_{W1})/q}{(1 - R^2{}_{W2})/(n-k-1)} \tag{5.0}$$

Where:

q = number of restrictions introduced between models
n = number of observations
k = number of variables in W2 including the constant

The 5% critical value for the F distribution for numerator degrees of freedom (q) and denominator degrees of freedom (n-k-1) is 3.84. The F statistic for model W2 compared to W1 is:

$$F = \frac{(0.031 - 0.030)/1}{(1 - 0.031)/(4029 - 13 - 1)} = 4.14 \tag{5.1}$$

Since 4.14 is greater than the F critical statistic for 5% significance, W2 is an improvement over the previous model, W1. Comparing models S1 and S2, the inclusion of the LCV direct effect is not an improvement. Using more significant figures than reported in Table 7 for the $R^2$ results in:

$$F = \frac{(0.0364 - 0.0357)/1}{(1 - 0.0364)/(4029 - 13 - 1)} = 2.92 \tag{5.2}$$

This is less than the F critical of 3.84. Model S2 is not a significant improvement over S1. F statistics are reported in the last row in all tables using fixed effects estimation.

The magnitude of the coefficient is important to understanding the practical significance of a variable. When interpreting this variable, it is important to remember that it is centered for each year. Holding all other variables constant, an increase in LCV scores by 10 over the average LCV score for any given year increases wind energy manufacturing clustering by 0.114*(0.10) = 0.0114. The average number of wind component and system manufacturers across the panel is 134. To convert 0.0114 to number of firms, I multiply 134 times 0.0114, resulting in an increase of 1.5 in manufacturing firms in an MSA. If the dependent variable, Wind ILQ, increases by 0.0114, a cluster increases by 1 to 2 more manufacturers. For smaller cities such as Missoula, Montana, this would be considered successful economic development, but for larger cities such as New York City, this would be practically insignificant. The practical significance of the institutional logic variable is small. A similar calculation for practical effect on solar manufacturing clustering results in an increase of 1.8, so about the same increase of 1 to 2 more solar system or component manufacturers for an increase in 10 over the average LCV scores for a year.

Testing Moderating Effects on Pecuniary Externalities

Hypothesis 2a predicts a positive moderating relationship from a congruous institutional logic on the relationship between pecuniary externalities and clustering. For the wind manufacturing cluster model, W3, the coefficient on LCV is positive and significant while the interaction term LCV X Wind Energy Labor Pool is negative and not significant. For the solar manufacturing cluster model, S3, the coefficient on LCV and the interaction term LCV X Solar Energy Labor Pool are both positive and significant. Just looking at significance of the coefficient estimates, it appears hypothesis 2a is not supported in the wind model and is supported in the solar model.

The practical significance of model W3 can be understood only through the direct effect of the LCV variable. Since the interaction term is not significant (p value=0.39) it is inappropriate to use it to predict its influence on the dependent variable. Holding all other variables constant, an increase in LCV scores by 10 over the average LCV score any given year increases wind energy manufacturing clustering by 0.116*(0.10) = 0.0116. This direct influence once again correlates with an increase of 1 to 2 more manufacturers in a MSA. The practical significance of the institutional logic variable is small.

To determine if the inclusion of the direct effect and moderating effect are an improvement to the wind model, I test to see if jointly they have a nonzero partial effect on the dependent variable. The 5% F critical is 3.00, for a numerator degrees of freedom and a denominator degrees of freedom of 4014. The F statistic comparing W1 and W3 is:

$$F = \frac{(0.031-0.030)/2}{(1-0.031)/(4029-14-1)} = 2.083 \quad (5.3)$$

indicating that the inclusion of the direct and moderating effect on pecuniary externalities is not jointly significant.

For solar model S3, the coefficients on LCV and the interaction term LCV X Solar Energy Labor Pool are both positive and significant. The practical significance of model S3 can be understood by taking the partial derivative of LCV on Solar ILQ:

$$\frac{\partial ILQ}{\partial LCV} = \beta_{LCV} + \beta_{LCVXLabor} LaborPool \quad (5.4)$$

From model S3, the values for $\beta_{LCV} = 0.168$ and $\beta_{LCV\,X\,Labor} = 0.083$, can be inserted into the partial effects equation 5.4, resulting in:

$$\frac{\partial ILQ}{\partial LCV} = 0.168 + 0.083(LaborPool) \quad (5.5)$$

By setting equation 5.5 equal to zero and solving for Labor Pool, we see that any Labor Pool value greater than -2.024 will have a positive influence on solar energy manufacturing clustering. The values of the *centered* Solar Labor Pool variable range from -3.56 to 2.81, so it is possible for a small value for Solar Labor Pool to overcome the positive influence of the LCV variable. By inserting an interesting value for labor pool into the partial derivative, we see the practical significance. An increase by one for the skilled labor pool in a MSA over the average value for Labor Pool, results in 0.168 +

0.083(1) = 0.251. This variable is logged, the exponential of 1 is equal to 2.718. So an increase of 2,718 people in the labor pool over the average results in an increase of 0.251 in Solar ILQ. An increase of 0.251 in Solar ILQ is equal to that value multiplied by the average number of firms of 158, which is an increase of 40 new firms in a MSA. The indirect effect for a congruous institutional logic is practically significant even for larger cities.

The significance on the individual coefficients does not indicate significance when considered separately. I need to test if they are jointly significant, not just look at whether each variable is individually significant (Wooldridge, 2003). The F statistic comparing S1 and S3 is:

$$F = \frac{(0.037 - 0.036)/2}{(1 - 0.037)/(4029 - 14 - 1)} = 2.083 \qquad (5.6)$$

Since the 5% F critical is 3.00, the inclusion of the direct and moderating effect on pecuniary externalities is not jointly significant for the solar model. The variables of LCV and LCV X Solar Energy Labor Pool are not an improvement in the model. In the next section I discuss the results of the moderating effect of a congruous institutional logic on the second type of externality.

## Testing Moderating Effects on Technological Externalities

Hypothesis 2b predicts a positive moderating relationship from a congruous institutional logic on the relationship between technological externalities and clustering. For the wind manufacturing clustering model, W4, the coefficient on LCV is positive and significant, while the interaction term LCV X Wind R&D is positive but not significant.

For the solar manufacturing cluster model, S4, the coefficient on LCV and the interaction term LCV X Solar R&D are both positive and significant. Hypothesis 2a is not supported in the wind model and is supported in the solar model.

The practical significance of model W4 can be understood through the direct effect of the LCV variable on clustering. Since the interaction term is not significant (p value = 0.586) it is inappropriate to use it to predict its influence on the dependent variable. Holding all other variables constant, an increase in LCV scores by 10 over the average LCV score for any given year increases wind energy manufacturing clustering by 0.122*(0.10) = 0.0122, resulting in an increase of 2 more manufacturers in a MSA. The practical significance of the institutional logic variable is small.

To determine if the inclusion of the direct effect and moderating effect are an improvement to the wind model, I test to see if jointly they have a nonzero partial effect on the dependent variable. The 5% F critical is 3.00, for a numerator degrees of freedom of two and a denominator degrees of freedom of 4014. The F statistic comparing W1 and W4 is:

$$F = \frac{(0.031 - 0.030)/2}{(1 - 0.031)/(4029 - 14 - 1)} = 2.083 \tag{5.7}$$

indicating that the inclusion of the direct and moderating effect on pecuniary externalities is not an improvement in the model.

For solar model S4, the coefficients on LCV and the interaction term LCV X Solar Energy Labor Pool are both positive and significant. The practical significance of model S4 can be understood by taking the partial derivative of LCV on Solar ILQ:

$$\frac{\partial ILQ}{\partial LCV} = 0.236 + 0.088(R\,\&\,D) \tag{5.8}$$

Setting equation 5.8 equal to zero and solving for Solar R&D, shows that any R&D value greater than -2.68 will have a positive influence on solar energy manufacturing clustering. The values of the centered Solar R&D variable range from -3.61 to 8.67, so it is possible for a small value for Solar R&D to overcome the positive influence of the LCV variable. We can examine practical significance by inserting an interesting value for Solar R&D. An increase by one in the research and development spending in a MSA over the average R&D spending results in 0.236 + 0.088(1) = 0.324. So an increase of $2,718,000 in the R&D spending in relevant engineering disciplines in a MSA's universities over the average R&D spending results in an increase of 0.324 in Solar ILQ. An increase of 0.324 in Solar ILQ is equal to that value multiplied by the average number of firms of 158. This results in an increase of 51 new firms in a MSA. The indirect effect for a congruous institutional logic is practically significant even for larger cities.

To test if they are jointly significant, not just look at whether each variable is individually significant (Wooldridge, 2003), I use an F test. The F statistic comparing S1 and S4 is:

$$F = \frac{(0.039 - 0.036)/2}{(1 - 0.039)/(4029 - 14 - 1)} = 6.265 \tag{5.9}$$

Since the 5% F critical is 3.00, the inclusion of the direct and moderating effect on pecuniary externalities is jointly significant and an improvement for the solar model.

Testing Technological Uncertainty Moderating Effects on Congruous Logic

Hypothesis 3 predicts a moderating relationship from technological uncertainty on a congruous institutional logic's positive direct effect on clustering. Greater uncertainty enhances the direct effect of a congruous institutional logic on clustering in MSAs. To test this hypothesis, I draw on the historical difference in the viability between wind energy production and solar energy production. As explained in Chapter 4, wind energy has been more commercially viable as an alternative energy generating technology than solar or photovoltaic energy. For example, in 1980, the projected cost of energy generated by wind was 198 mills/kWhr, which decreased to 57 mills/kWhr in 1995. The projected cost of energy generated by solar was 1,814 mills/kWhr which decreased to 275 mills/kWhr in 1995 (Mcveigh et al., 1999). Throughout the time span for the study, wind was a more viable and stable technology.

I test hypothesis 3 by comparing the coefficient on the variable representing the congruous institutional logic, the League of Conservation Voters scores (LCV), between the wind and solar models. Hypothesis 3 predicts that the LCV coefficient is significantly greater in the solar model, S2, than the wind model, W2. The null hypothesis for the t-test sets the coefficients for each model equal to each other:

$$Ho: \beta_{LCVwind} - \beta_{LCVsolar} = 0 \tag{5.10}$$

Using the standard error for each coefficient and sample size of 4029, a t-test rejects the null hypothesis (t = -33.98, p value = 0.000). The coefficients are significantly different with the LCV coefficient for the solar model being greater than that for the wind model. Hypothesis 3 is supported at 1% significance.

The hypotheses were tested with fixed effects estimation and a t-test between explanatory variable coefficients in the two models. Hypothesis 1 is supported for the wind model, hypothesis 2a is not supported, hypothesis 2b is supported in the solar model, and hypothesis 3 is supported. However, hypotheses testing cannot determine if the causal relationship is bi-directional. In the next section, I test for reverse causality in the wind and solar models.

## Causal Relationship

To ensure that the support for the hypotheses is causal and not spurious, I need to determine if the reverse relationship is occurring. Do LCV scores increase because MSAs have more firms in renewable energy manufacturing? I examine the causal relationship in two ways. First, I lag the dependent variable in the model and regress it on the congruous institutional logic variable (Granger, 1969). Second, I regress the model on only those observations where the previous year's clustering was zero.

Using the longitudinal nature of the data, I regress the Wind ILQ and Solar ILQ variable, lagged one year, on the LCV variable. Tables 8 and 9 show the results of the regression.

**Table 8.** Reverse Causality Regression for Wind Model, Fixed Effects Estimation, Dependent Variable - LCV

| | W5 | W6 |
|---|---|---|
| Population (thousands) [a, b] | 0.225*** | 0.225*** |
| | (0.051) | (0.051) |
| Change State Gross Product(%) [a] | 0.017 | 0.016 |
| | (0.104) | (0.104) |
| Change US GDP (%) [a] | -0.133 | -0.132 |
| | (0.208) | (0.208) |
| Avg Price of Elec ($/MBtu) [a] | 0.004 | 0.004 |
| | (0.003) | (0.003) |
| Commercial Interest Rate [a] | -0.001 | -0.001 |
| | (0.002) | (0.002) |
| Federal Incentive Indicator | -0.005 | -0.005 |
| | (0.006) | (0.006) |
| Supreme Court Ruling Indicator | -0.028 | -0.028 |
| | (0.019) | (0.019) |
| Trend | -0.004** | -0.004** |
| | (0.001) | (0.001) |
| IMR for Wind Model | 0.123* | 0.123* |
| | (0.064) | (0.064) |
| No. Wind Incentives | 0.014** | 0.014** |
| | (0.006) | (0.006) |
| Wind Generating Facilities [a, b] | -0.032*** | -0.032*** |
| | (0.011) | (0.011) |
| Wind Labor [a, b, c] | 0.024*** | 0.024*** |
| | (0.008) | (0.008) |
| Wind R&D [a, b, c] | -0.002 | -0.002 |
| | (0.003) | (0.003) |
| Wind ILQ (%) [a] | | -0.001 |
| | | (0.003) |
| Observations | 4028 | 4028 |
| MSAs | 252 | 252 |
| $R$-squared | 0.012 | 0.012 |
| F statistic (compared to model 1) | | 0 |

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

[a] lagged; [b] logged; [c] centered

**Table 9.** Reverse Causality Regression for Solar Model, Fixed Effects Estimation, Dependent Variable - LCV

| | S5 | S6 |
|---|---|---|
| Population (thousands) [a, b] | 0.254*** | 0.252*** |
| | (0.055) | (0.055) |
| Change State Gross Product(%) [a] | 0.091 | 0.080 |
| | (0.121) | (0.121) |
| Change US GDP (%)[a] | -0.188 | -0.174 |
| | (0.224) | (0.224) |
| Avg Price of Elec ($/MBtu) [a] | 0.003 | 0.003 |
| | (0.003) | (0.003) |
| Commercial Interest Rate [a] | -0.002 | -0.001 |
| | (0.002) | (0.002) |
| Federal Incentive Indicator | -0.008 | -0.008 |
| | (0.006) | (0.006) |
| Supreme Court Ruling Indicator | -0.030 | -0.029 |
| | (0.020) | (0.020) |
| Trend | -0.003** | -0.003** |
| | (0.002) | (0.002) |
| IMR for Solar Model | 0.179** | 0.171* |
| | (0.091) | (0.091) |
| No. Solar Incentives | 0.024*** | 0.023*** |
| | (0.006) | (0.006) |
| Solar Generating Facilities [a, b] | 0.008 | 0.014 |
| | (0.019) | (0.020) |
| Solar Labor [a, b, c] | 0.034* | 0.035* |
| | (0.019) | (0.019) |
| Solar R&D [a, b, c] | -0.003 | -0.004 |
| | (0.003) | (0.003) |
| Solar ILQ(%) [a] | | 0.004** |
| | | (0.002) |
| Observations | 4028 | 4028 |
| MSAs | 252 | 252 |
| R-squared | 0.012 | 0.013 |
| F statistic (compared to model 1) | | 4.07** |

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

[a] lagged; [b] logged; [c] centered

In the wind model, W6, the coefficient on the Wind ILQ variable is not significant. In the solar model, S6, the significant coefficient for Solar ILQ suggests a case of mutual causality. It suggests that if a MSA increases by 10 firms, meaning the Solar ILQ increases by 0.20, the LCV score will increase by 0.004*0.20 = 0.008. LCV is reported as a percent, so that scales to an increase in a MSA's LCV score over the average by 0.80. The practical significance is very small. Although reverse causality is present in the solar model, it is of little practical significance. Causality in the model is as hypothesized.

I examine causality further by isolating instances when clustering first appears. I identified 48 cases in wind clustering and 56 cases in solar manufacturing clustering where clustering emerged after the previous time period had zero clustering. Selecting all observations for which the previous time period had no clustering and then regressing on the dependent variable eliminates any potential recursive influence of clustering on LCV scores. The regression results are in Tables 10 and 11.

**Table 10.** Regression on First Emergence of Wind Energy Manufacturing Clustering

| DV – Wind ILQ | W7 | W8 |
|---|---|---|
| Population (thousands) [a, b] | -0.191 | -0.199 |
| | (0.332) | (0.318) |
| Inverse Mills Ratio | -3.295 | -3.323 |
| | (2.458) | (2.549) |
| Change State Gross Product (%) [a] | 3.205 | 3.666 |
| | (4.175) | (5.192) |
| Change US GDP (%) [a] | -27.048** | -26.057* |
| | (11.279) | (13.364) |
| Avg Price of Elec ($/MBtu) [a] | -0.045 | -0.046 |
| | (0.059) | (0.062) |
| Commercial Interest Rate [a] | 0.091 | 0.076 |
| | (0.139) | (0.191) |
| Federal Incentive Indicator | -0.093 | -0.090 |
| | (0.320) | (0.320) |
| Supreme Court Ruling Indicator | -0.025 | -0.061 |
| | (0.778) | (0.866) |
| No. Wind Incentives | -0.090 | -0.082 |
| | (0.147) | (0.152) |
| Trend | -0.056 | -0.059 |
| | (0.078) | (0.084) |
| Wind Generating Facilities [a, b] | 0.238 | 0.248 |
| | (0.454) | (0.479) |
| Wind Labor [a, b, c] | -0.115 | -0.115 |
| | (0.119) | (0.120) |
| Wind R&D [a, b, c] | 0.032 | 0.032 |
| | (0.080) | (0.085) |
| LCV (/100) [a c] | | 0.241 |
| | | (1.279) |
| Observations | 48 | 48 |
| R-squared | 0.292 | 0.294 |
| F statistic | | 0.0960 |

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

[a] lagged; [b] logged; [c] centered

**Table 11.** Regression on First Emergence of Solar Energy Manufacturing Clustering

| DV – Solar ILQ | S7 | S8 |
|---|---|---|
| Population (thousands) [a, b] | 0.095 | 0.094 |
| | (0.233) | (0.235) |
| Inverse Mills Ratio | -6.573*** | -6.889** |
| | (2.249) | (2.592) |
| Change State Gross Product (%) [a] | -38.565*** | -37.715*** |
| | (11.181) | (10.911) |
| Change US GDP (%) [a] | 44.447** | 42.653** |
| | (16.866) | (16.585) |
| Avg Price of Elec ($/MBtu) [a] | -0.048 | -0.047 |
| | (0.048) | (0.047) |
| Commercial Interest Rate [a] | -0.105 | -0.093 |
| | (0.075) | (0.074) |
| Federal Incentive Indicator | -0.225 | -0.250 |
| | (0.417) | (0.438) |
| Supreme Court Ruling Indicator | 1.818* | 1.832* |
| | (1.040) | (1.064) |
| No. Solar Incentives | 0.022 | 0.001 |
| | (0.218) | (0.232) |
| Trend | -0.067 | -0.066 |
| | (0.091) | (0.092) |
| Solar Generating Facilities [a, b] | 0.931 | 0.823 |
| | (0.653) | (0.704) |
| Solar Labor [a, b, c] | 0.087 | 0.076 |
| | (0.109) | (0.112) |
| Solar R&D [a, b, c] | -0.048 | -0.063 |
| | (0.073) | (0.077) |
| LCV (/100) [a c] | | 0.574 |
| | | (0.839) |
| Observations | 56 | 56 |
| R-squared | 0.477 | 0.481 |
| F statistic | | 0.324 |

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
[a] lagged; [b] logged; [c] centered

Regressing on a cross-section of MSAs in the year they first exhibit clustering results in positive but insignificant coefficient estimates. From these estimations, it is difficult to say much about the relationship between LCV and clustering. The sample sizes are small and the observations come from different years in the dataset. In addition, looking at the F statistic, models including LCV are not a significant improvement over the base model. It is better to use the Granger method to understand reverse causality. The Granger (1969) method indicates the causality is in the direction predicted by the model, and the reverse causality that does occur in the solar data has a very small effect. In the next section, I use a Hausman-Taylor estimation to understand the influence of time-invariant control variables in the model.

## Influence of Time Invariant Regressors

Although including time-invariant regressors was not necessary to test the hypotheses, by including them in the model I am able to understand more about the clustering phenomena. I employ a Hausman-Taylor (1981) estimation method to understand how the time-invariant regressors of wind potential, solar potential, and presence of a national laboratory influence clustering. Hausman-Taylor estimates the coefficients of the time-invariant regressors with random effects while maintaining fixed effects estimation for the rest of the regressors. Table 12 presents the results of the Hausman-Taylor estimation for wind energy manufacturing clusters, and Table 13 presents the results for solar energy manufacturing clusters.

**Table 12.** Hausman-Taylor Estimation for Wind Model

| DV - Wind ILQ | W9 | W10 | W11 | W12 |
|---|---|---|---|---|
| Population (thousands) [a, b] | 0.438*** | 0.420*** | 0.455*** | 0.400** |
| | (0.159) | (0.160) | (0.155) | (0.161) |
| Inverse Mills Ratio | 0.676** | 0.671** | 0.670** | 0.676** |
| | (0.301) | (0.301) | (0.300) | (0.301) |
| Change State Gross Prod (%) [a] | -0.210 | -0.187 | -0.177 | -0.185 |
| | (0.528) | (0.528) | (0.527) | (0.529) |
| Change US GDP (%) [a] | 1.333 | 1.305 | 1.291 | 1.304 |
| | (1.037) | (1.037) | (1.035) | (1.038) |
| Avg Price of Elec ($/MBtu) [a] | -0.039*** | -0.038*** | -0.039*** | -0.039*** |
| | (0.014) | (0.014) | (0.014) | (0.014) |
| Commercial Interest Rate [a] | -0.009 | -0.009 | -0.009 | -0.009 |
| | (0.007) | (0.007) | (0.007) | (0.007) |
| Federal Incentive Indicator | -0.065** | -0.065** | -0.065** | -0.065** |
| | (0.028) | (0.028) | (0.028) | (0.028) |
| Sup Court Ruling Indicator | 0.126 | 0.127 | 0.128 | 0.129 |
| | (0.088) | (0.088) | (0.088) | (0.088) |
| No. Wind Incentives | 0.069** | 0.068** | 0.068** | 0.067** |
| | (0.027) | (0.027) | (0.027) | (0.027) |
| Trend | 0.010 | 0.010 | 0.010 | 0.010 |
| | (0.006) | (0.006) | (0.006) | (0.006) |
| Wind Generating Facilities [a, b] | -0.365*** | -0.362*** | -0.362*** | -0.363*** |
| | (0.048) | (0.048) | (0.048) | (0.048) |
| Wind Labor [a, b, c] | 0.072** | 0.070** | 0.069** | 0.070** |
| | (0.033) | (0.033) | (0.033) | (0.034) |
| Wind R&D [a, b, c] | 0.012 | 0.013 | 0.013 | 0.012 |
| | (0.016) | (0.016) | (0.016) | (0.016) |
| Wind Potential ($km^2$) [b] | 0.006 | 0.005 | 0.010 | 0.002 |
| | (0.047) | (0.048) | (0.045) | (0.048) |
| National Lab Indicator | 22.804*** | 22.885*** | 20.517*** | 24.136*** |
| | (5.659) | (5.697) | (5.129) | (5.648) |
| LCV (/100) [a, c] | | 0.114 | 0.116 | 0.124 |
| | | (0.077) | (0.077) | (0.079) |
| LCV X Wind Labor [a, b, c] | | | -0.028 | |
| | | | (0.040) | |
| LCV X Wind R&D [a, b, c] | | | | 0.014 |
| | | | | (0.021) |
| Observations | 4029 | 4029 | 4029 | 4029 |
| MSAs | 252 | 252 | 252 | 252 |
| $\chi^2$ (d.f) | 151.97 (15) | 153.69 (16) | 156.59 (17) | 155.29 (17) |
| $\chi^2$ Difference | | 1.72 | 4.62* | 3.32 |

* significant at 10%; ** significant at 5%; *** significant at 1%

[a] lagged; [b] logged; [c] centered

**Table 13.** Hausman-Taylor Estimation for Solar Model

| DV - Solar ILQ | S9 | S10 | S11 | S12 |
|---|---|---|---|---|
| Population (thousands) [a, b] | 0.749*** | 0.720*** | 0.902*** | 0.674*** |
| | (0.254) | (0.255) | (0.226) | (0.253) |
| Inverse Mills Ratio | 1.455*** | 1.458*** | 1.393*** | 1.508*** |
| | (0.544) | (0.545) | (0.534) | (0.545) |
| Change State Gross Prod (%) [a] | 2.251*** | 2.291*** | 2.315*** | 2.360*** |
| | (0.809) | (0.809) | (0.799) | (0.811) |
| Change US GDP (%) [a] | -2.294 | -2.356 | -2.336 | -2.437 |
| | (1.526) | (1.526) | (1.509) | (1.529) |
| Avg Price of Elec ($/MBtu) [a] | 0.018 | 0.019 | 0.019 | 0.019 |
| | (0.021) | (0.021) | (0.020) | (0.021) |
| Commercial Interest Rate [a] | -0.012 | -0.012 | -0.012 | -0.012 |
| | (0.010) | (0.010) | (0.010) | (0.010) |
| Federal Incentive Indicator | -0.074* | -0.073* | -0.076* | -0.073* |
| | (0.039) | (0.039) | (0.039) | (0.039) |
| Sup Court Ruling Indicator | -0.146 | -0.148 | -0.147 | -0.138 |
| | (0.128) | (0.128) | (0.126) | (0.128) |
| No. Solar Incentives | 0.103*** | 0.100*** | 0.104*** | 0.097*** |
| | (0.034) | (0.034) | (0.034) | (0.034) |
| Trend | -0.013 | -0.013 | -0.014 | -0.013 |
| | (0.009) | (0.009) | (0.009) | (0.009) |
| Solar Generating Facilities [a, b] | -1.423*** | -1.432*** | -1.431*** | -1.451*** |
| | (0.132) | (0.132) | (0.130) | (0.132) |
| Solar Labor [a, b, c] | -0.041 | -0.046 | -0.032 | -0.060 |
| | (0.099) | (0.100) | (0.095) | (0.100) |
| Solar R&D [a, b, c] | 0.004 | 0.005 | 0.007 | 0.006 |
| | (0.022) | (0.022) | (0.021) | (0.022) |
| Solar Potential ($km^2$) [b] | -0.083 | -0.082 | -0.053 | -0.086 |
| | (0.056) | (0.057) | (0.048) | (0.058) |
| National Lab Indicator | 38.817*** | 39.388*** | 25.581*** | 42.135*** |
| | (12.233) | (12.310) | (8.855) | (11.660) |
| LCV (/100) [a, c] | | 0.170 | 0.163 | 0.232** |
| | | (0.108) | (0.108) | (0.110) |
| LCV X Solar Labor [a, b, c] | | | 0.081 | |
| | | | (0.067) | |
| LCV X Solar R&D [a, b, c] | | | | 0.088*** |
| | | | | (0.029) |
| Observations | 4029 | 4029 | 4029 | 4029 |
| MSAs | 252 | 252 | 252 | 252 |
| $\chi^2$ | 168.76 (15) | 170.77 (16) | 179.70 (17) | 182.11 (17) |
| $\chi^2$ Difference | | 2.01 | 10.94*** | 13.35*** |

* significant at 10%; ** significant at 5%; *** significant at 1%

[a] lagged; [b] logged; [c] centered

The most striking result using a Hausman-Taylor estimation method is the very large, positive, and significant coefficient for the presence of a national laboratory in a MSA. The three MSAs with national laboratories are Boulder, Colorado; Albuquerque, New Mexico; and Berkeley, California. Although the variable representing research and development was not significant in the models, the national laboratory indicator is. It appears that the knowledge spillover variable may be too broad and not specific enough to wind or solar energy research.

Although the explanatory variables are no longer significant at the 10% level in the Hausman-Taylor model, those that were supporting hypotheses in the fixed effects model are behaving in similar fashion, but with reduced significance. The testing of hypothesis 1 relies on the estimate for the LCV coefficients. The coefficients are about the same value, with the wind model having a p value of 0.86 and the solar model having a p value of 0.88. In the fixed effects estimation, hypothesis 2a was partially supported by the solar model, but not by the wind model. For hypothesis 2a the coefficients are similar to those in the fixed effects model, but they lose some significance. In the solar models, the direct effect has a p value of 0.87 and the moderating effect has a p value of 0.77. Similarly, for hypothesis 2b, which was supported by the solar model, is still supported in the Hausman-Taylor estimation. Hypothesis 3 was supported in the fixed effects estimation and is supported in the Hausman-Taylor estimation (t value= 26.8, p value = 0.00).

## Discussion of Results

This study finds support for some but not all of the hypotheses. Looking at the estimates for the explanatory variables in the wind models, only the variable for the congruous institutional logic's direct effect is significant. While in the solar models, the estimates for the direct and moderating effect of a congruous institutional logic are significant in the solar model. Although the explanatory variables for hypothesis 1 and hypothesis 2a in the solar model are significant, unfortunately the F statistic is not significant. The hypotheses are not supported when the F statistic does not indicate that the restricted model is an improvement over the unrestricted model. I find causality in the direction predicted with results similar to the fixed effects estimation when I use a Hausman-Taylor estimation. The results for the hypotheses are summarized in Table 14.

**Table 14.** Summary of Results

| Hypothesis | Wind Model | Solar Model |
|---|---|---|
| 1 – Congruous institutional logic has a positive direct effect | Yes | No |
| 2a – Congruous institutional logic has a positive moderating effect on pecuniary externalities | No | No |
| 2b - Congruous institutional logic has a positive moderating effect on technological externalities | No | Yes |
| 3 - Technological uncertainty has a positive moderating effect on congruous institutional logic | Yes | |

The results support the direct effect of a congruous institutional logic on clustering. The partial support for the moderating effect by a congruous institutional logic on the positive direct effect of externalities on clustering highlights the difference between the two technologies. The pattern of partial support for the solar models, but not the wind models, indicates more influence from a congruous institutional logic when a technology is not commercially viable. Since the dominant design was not determined for solar energy during the time span of the study as it was for wind energy, it appears that the moderating effect is significant during greater technological flux.

The large practical effect of the interaction variable on clustering in the solar models is surprising. While the direct effect in wind and solar models is modest—an increase in 10 over the LCV average results in 2 new firms—the moderating effect in the solar models was quite pronounced. An increase in 2,718 skilled laborers over the average results in an increase of 40 firms. An increase in $2,718,000 in R&D at universities over the average results in an increase of 51 firms. Although we might expect the causal relationship to be reciprocal, the wind model did not show reverse causality and the solar model's reverse causality was practically very small. If a MSA increases its solar energy cluster by 10 firms, the MSA's LCV score would increase by 0.08 over the average.

The national laboratory indicator's large and strongly significant coefficients are surprising. Although I expected there to be an influence, I did not expect it to be greater than the research and development spending by the universities located in a MSA. This indicates the incredible value a national laboratory has for local economic development.

In the next section, I discuss several limitations to this study that influence the ability to generalize the findings.

## Limitations

Testing hypotheses about regional clusters present several challenges. The first was in selection of an empirical context. The second was in operationalizing the variables, particularly clusters, and the third is in generalizability.

The first limitation to consider is the choice of empirical context. Choosing the post-PURPA energy industry provides an ideal environment in which to explore the institutional influences of regional cluster emergence, due to the clear link between a pro-environment institutional logic and the pro-environmental perceptions of manufacturing of renewable energy generation equipment (Mitchell et al., 1992). While potentially an extreme case (Yin, 2003), it is precisely that clear link which allows for the identification and analysis of human populations with pro-environmental sentiments, and to test the influence of this pro-environmental sentiments on the emergence of regional clusters. While such 'clarity' may not be as obvious in less demarcated and represented institutional logics, the implications of this study do provide additional insight to both academics and practitioners in understanding how institutions influence regional cluster emergence. In other contexts, public policy makers may have difficulty in identifying congruous institutional logics for other regional clusters with hazier ideological indicators.

The second limitation of this study is the operationalization of the variables. One contribution of this study to this area of research is that I represent clusters as interrelated firms, not just the density of one organizational form. However, I was only able to represent clusters of firms in the supply chain for wind and solar energy equipment manufacturers. I assumed that if a manufacturer produced equipment that is a component in an energy system that it is in a cluster. Given the nature of my study, to test across many MSAs for many years, I was not able to collect data at the fine granularity of actual business relationships in clusters. Another limitation is in the operationalization of knowledge spillover. The research spending of universities in relevant engineering disciplines appears to be too broad of a measure to target spillover to renewable energy manufacturing. However, the large coefficient on the presence of a national laboratory, as shown in Tables 12 and 13, indicates that spillover is an important positive externality for cluster emergence.

The third limitation is a concern over generalizability of these findings. The sample for this study is close to the entire population of U.S. MSAs, so its predictive ability to other U.S. MSAs is limited to around 30 cities not included in the sample. However, the findings on institutional fit for business activities with congruous institutional logics are generalizable. For example, if we could measure 'wholesomeness' across MSAs, we might be able to explore how that influences cluster emergence in many cities, as it did in the musical theater cluster of Branson, Missouri (Chiles et al., 2004). There are many institutional logics that can influence geographical regions (Thornton & Ocasio, 2008). Measuring them is a more difficult challenge than recognizing them. Due to the difficulty in measuring institutional logics that fit specific business cluster activities, it may be difficult to generalize the findings of this study in other contexts. Despite these limitations, this study presents several theoretical, managerial, and policy implications. I review these implications in the next chapter.

# CHAPTER VI

# CONCLUSION

For more than a century, researchers have studied regional clusters (Marshall, 1890/1920), and yet, we are still unsuccessful in predicting where clusters will emerge (Fromhold-Eisebith & Eisebith, 2005). Predicting the appearance of clusters is not as easy as saying that once one firm has seeded in a region then others will follow. Although there are software development clusters in Seattle, Washington, and the Bay Area in California, the lack of software development clusters in Phoenix, Arizona, and Fargo, North Dakota, are evidence of the fallacy in that statement.

To explain cluster emergence, researchers have explored and theorized the benefits to pecuniary (Rosenthal & Strange, 2007) and technological externalities (Lawson, 1999; Tallman et al., 2004). Although hinted at and used as an explanation, institutional influences have rarely been measured (noted exception: Chiles et al., 2004; Saxenian, 1994) particularly in varying levels across multiple regions to determine influence on business activity. This dissertation builds on these prior studies, by investigating the following research question: *How do institutions, specifically varying levels of a congruous institutional logic, affect regional cluster emergence?* To answer this question, I use an institutional logics framework to model how cluster emergence is influenced by various factors, such as supportive institutional logics, knowledge spillover, labor pooling, and technological uncertainty. In this chapter I provide an overview of the study and address its theoretical, managerial, and public policy implications.

## Overview and Summary

In this section I provide a brief overview of this research project. To begin this study, I reviewed prior research and identified gaps in the current understanding of how institutions influence cluster emergence. My theoretical model, based on an institutional logics framework, fills the identified gaps in prior research. Tests of the hypotheses developed from the theoretical model demonstrated support for institutional influences on clustering that is enhanced by technology uncertainty.

### Prior Research

Since the benefits from regional clusters derive from positive externalities, I organized the literature review using Scitovsky's two external economies: pecuniary and technological (1957). Beneficial pecuniary externalities improve the profitability of firms by decreasing cost of inputs or increasing the price for outputs. Improved labor pooling is an example of a pecuniary externality for clustered firms. Beneficial technological externalities improve the profitability of firms by increasing their production function. Receiving knowledge spillover is an example of a technological externality for clustered firms. To find gaps, I reviewed research at the intersection of these externalities and three types of institutions (Scott, 2001)—regulatory, normative, and cultural-cognitive.

Prior regional cluster research on pecuniary externalities finds many benefits to clustering, including enhanced access to existing resources and reduced costs of inputs, increased legitimacy, and access to specialized inputs. Research at the intersection of pecuniary externalities and institutions finds that regulatory institutions can increase clustering by increasing prices for outputs (i.e. Russo, 2003), or through improved access to inputs such as labor (i.e. Rosenthal & Strange, 2007). Although there is no prior research on clusters and normative institutions, cultural-cognitive institutions can increase clustering through institutional grooming that improves access to necessary inputs (Chiles et al., 2004). It is clear there is a lack of research addressing the impact on clusters by institutional influences that vary across many regions.

Prior regional cluster research on technological externalities finds many benefits to clustering, including knowledge spillover, innovation, knowledge creation within networks, and knowledge creation from social resources such as experience. Research at the intersection of technological externalities and institutions finds that regulatory institutions can facilitate knowledge spillover (Stuart & Sorenson, 2003b). Normative institutions can increase clustering by encouraging support for businesses connected through family networks (Piore & Sabel, 1984). Cultural-cognitive institutions can increase clustering by supporting knowledge sharing or entrepreneurial behaviors (Saxenian, 1994). Unfortunately, prior research usually represents clusters comprised of only one type of organizational form. In two studies which examine clusters of interrelated firms (Chiles et al., 2004; Saxenian, 1994), the authors undertake an in-depth examination of already-established clusters. I find a lack of prior research that examines how varying levels of institutions influence clustering across multiple regions.

**Gaps**

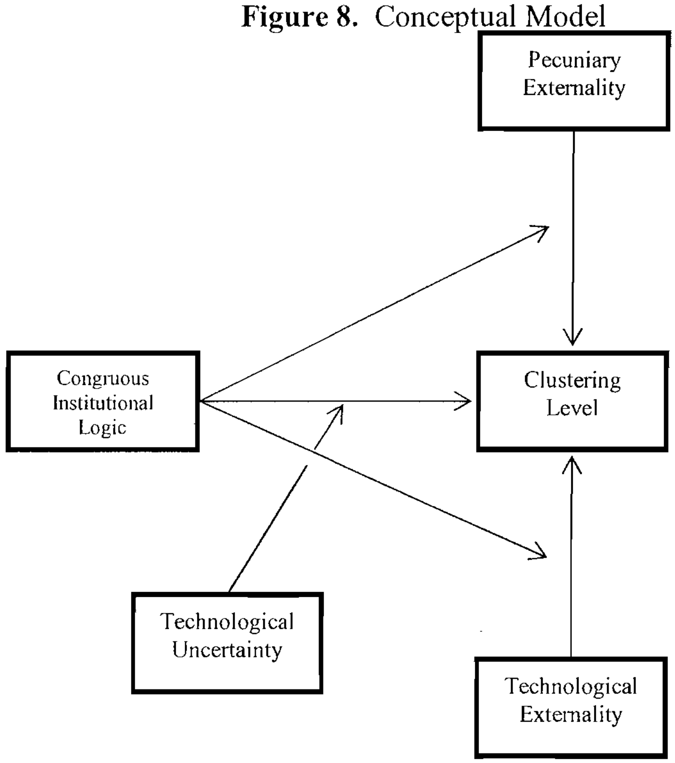
The literature review identifies several areas where this study can fill gaps in our understanding about institutional influences on cluster emergence. Areas in which there is need for improvement in research include comparing across multiple regions, measuring clusters as interrelated firms, and representing more than one type of institution. This study increases understanding about cluster emergence by comparing influences on clustering across many regions. Regions with clustering must be compared to regions without clustering. In contrast with prior research, this study samples across multiple regions rather than just regions with retrospectively identified clusters. This study improves understanding about cluster emergence by measuring clusters as interrelated firms. Prior research has suffered from sampling only one organizational form (Audia et al., 2006; Freeman et al., 2006). This study improves measurement of clusters by using clusters of interrelated firms rather than clusters of one organizational form. A methodological contribution of this study is the measure developed to represent agglomeration of interrelated firms, the interrelated location quotient (ILQ), which is a modification of the commonly used location quotient (O'Donoghue & Gleave, 2004).

Additionally, this study improves understanding about institutional influences on cluster emergence by modeling more than one type of institutional influence. Only a few studies have examined more than one type of institutional influence on clusters. Those notable exceptions are Saxenian (1994), Russo (2003), and Chiles and colleagues (2004). However, in contrast with this study, Saxenian and Chiles and colleagues examined only established clusters, while Russo measured clusters as a density of only one type of organizational form. In order to better understand the influence of institutions, this study investigates both regulatory and cultural-cognitive institutions.

### Theoretical Model

In order to include institutional influences on regional cluster emergence, the new theoretical model incorporates an institutional logics framework into an existing cluster model. Institutional logics are belief systems that guide the actions of organizations and individuals (Friedland & Alford, 1991). Prior research on institutional logics has shown them to exert influence at the level of geographic communities (Thornton & Ocasio, 2008), and as such are suitable to use in understanding the institutional influences on cluster emergence. Figure 8 shows the conceptual model resulting from the integration of institutional logics into an existing model of cluster emergence.

**Figure 8.** Conceptual Model



Prior research has shown that institutional logics exert a direct influence on the behaviors of organizations and individuals (Haveman & Rao, 1997; Lounsbury, 2007; Thornton & Ocasio, 1999). For example, the prevalence of a community-banking institutional logics results in more foundings of community banks (Marquis & Lounsbury, 2007). When an institutional logic fits with a business's activities, as in the example with community-banking, it is understood to be congruous. In another example, an institutional logic of Progressivism advocates personal savings, and as Progressivism spread across the U.S., this institutional logic resulted in a noticeable increase in the founding of more thrift organizations (Haveman & Rao, 1997). My theoretical model incorporates a positive direct effect of congruous institutional logic on clustering.

In addition to direct influence, prior research has shown that institutional logic exerts a moderating influence on the behaviors of organizations and actors (Thornton, 2004). For example, while studying publishing in higher education, Thornton found that an editorial institutional logic had a greater moderating influence on executive succession than a market institutional logic. Thornton identifies an editorial logic as valuing prestige for a publishing house contrasted with a market logic valuing profitability. The editorial logic is a specific logic because it is linked to an industry or profession, while the market logic is a universal logic that is widely held throughout the general population. Thornton generalizes this finding to conclude that specific logics moderate business activities more so than universal logics. My theoretical model incorporates the moderating influence of institutional logics on the clearly established direct affect of positive pecuniary and technological externalities on clustering. My second hypothesis predicts that a congruous institutional logic enhances the positive direct affect of each type of externality on clustering.

Finally, since uncertainty amplifies the influence of institutions (DiMaggio & Powell, 1983) on firm activities, my model must incorporate uncertainty. This is relevant to regional clusters because researchers have found that decision makers seek information from geographically proximate institutional sources when faced with uncertainty (Davis & Greve, 1997; Marquis et al., 2007). There are many types of uncertainty, but since clusters form around an industry or technology, technological uncertainty is captured in the model. Specific to technology, whether and how it is used is also greatly influenced by institutional pressures (Martinez & Dacin, 1999). Prior research has shown that congruous institutions increase adoption of technology (Sine & Lee, 2009; Sommers & Napier, 1993). Since uncertainty has a moderating influence on institutional influences (DiMaggio & Powell, 1983), the third hypothesis predicts that technological uncertainty enhances the positive direct affect of a congruous institutional logic on clustering. Next, I summarize how I measured and tested these hypotheses.

**Analysis and Findings**

In order to measure and test the hypotheses, I needed an empirical setting in which I could clearly identify and measure a congruous logic with known business activities. This study uses the passage of the 1978 Public Utility Regulatory Policies Act (PURPA) as a catalyst in the renewable energy sector to examine the emergence of wind and solar energy manufacturing supply chain clusters. Human populations with pro-environmental institutional logics support, or in other words, are congruous with, the business activities of renewable energy manufacturing (Mitchell et al., 1992). This study measures the prevalence of this congruous institutional logic across U.S. metropolitan statistical areas (MSAs) with clustering of wind and solar energy manufacturers.

Factors used to measure this relationship include availability of skilled labor representing pecuniary externalities, and university research and development spending in relevant engineering disciplines representing technological externalities. Technological uncertainty is represented by the demonstrably different technological trajectories and commercial viability between the two types of technology—wind energy and solar energy. For example, solar energy had competing designs and drastically higher costs for energy produced from 1978 to 1995 (Gipe, 1995; Mcveigh et al., 1999). Since solar has greater technological uncertainty, the third hypothesis predicts that clustering for solar energy manufacturing will be influenced more by a congruous institutional logic than a congruous institutional logic will influence wind energy manufacturing.

I use a fixed effects estimation to test hypotheses 1 and 2. I use a mean difference, assuming unequal variances, t-test to compare the difference in the congruous institutional logic coefficients of the wind and solar models. Analysis supports hypotheses 1 in the wind models, indicating that congruous institutional logics do have a positive direct effect on clustering. However, the practical effect of hypothesis 1 is small.

I do not find support for hypothesis 2a, that a congruous institutional logic enhances the positive relationship of positive pecuniary externalities on clustering. I find support for hypothesis 2b in the solar model but not the wind model. In the solar model, I find that congruous institutional logics enhance the positive direct affect of positive technological externalities on clustering. The strong significance for this relationship in the solar model makes sense if we consider the differences in the technology trajectory between wind and solar energy. Throughout the time period for the study, 1978 - 1995, solar energy was not commercially viable and did not have a dominant design. On the other hand, wind energy settled on a dominant design in the early 1980s and, with the help of incentives and generous avoided cost rates, was commercially viable (Gipe, 1995). With such high levels of technological uncertainty, I expect institutional influences to be much more important (DiMaggio & Powell, 1983). Compared to the small practical effect from the direct relationship of congruous institutional logics on clustering, the practical effect of the moderating influence is quite large.

The importance of technological uncertainty in this context is reinforced by hypothesis 3. The t-test supports this hypothesis at a 1% significance level. As technological uncertainty increases, this positive direct affect of a congruous institutional logic is enhanced. The results from the hypotheses testing indicate that congruous institutional logics influence clustering, and that *how* they influence clustering depends on the technological uncertainty associated with the products or applications of a cluster. In wind energy manufacturing clusters, the direct affect of a congruous institutional logic is significantly supported, while in solar energy manufacturing clusters, the moderating affect of a congruous institutional logic is significantly supported. When comparing across the two models, the direct influence of the congruous institutional logic is significantly greater for solar energy manufacturing clusters than for wind energy manufacturing clusters. Another interesting result of the hypotheses testing is the large practical effect of the moderating influence of a congruous institutional logic compared to the smaller practical effect of its direct influence. When the measure for congruous institutional logic is increased to show an increase of 2 firms from the direct effect, an increase of 51 firms from the moderating effect on positive technological externalities is also shown. This suggests that as technological uncertainty increases, the influence of congruous institutional logics becomes increasingly more important.

Given the positive feedback loops in clusters, reverse causality is a genuine concern between institutional logics and levels of clustering. I test for reverse causality using a Granger method (1969). There is no indication of reverse causality in the wind models. Although there is reverse causality in the solar models, the practical effect is very small. Since I used fixed effects estimation, any time-invariant regressors are not estimated. Yet there are three dropped variables that might have relevance on cluster emergence in this empirical setting: wind potential, solar potential, and presence of a national laboratory. To examine the influence of time-invariant regressors I employ a Hausman-Taylor estimation. I find that the natural resource endowment of wind and solar energy potential is not significant on clustering. However, the most surprising significant coefficient in the analysis is the strong influence of knowledge spillover from national laboratories on clustering. In the next section, I consider the theoretical, managerial, and public policy implications of these findings.

## Implications

Positive feedback loops (Arthur, 1994) in regional clusters (Marshall, 1890/1920; Porter, 1998a) interest researchers, managers, and economic developers alike. Positive feedback loops provide increasing economic returns, improved innovation, and competitive advantages that are resistant to globalization trends. Because of this interest, they have been studied in many different disciplines, including economic geography, management, and sociology. To explain cluster emergence, researchers have explored and theorized the benefits from pecuniary (Rosenthal & Strange, 2007) and technological externalities (Lawson, 1999; Tallman et al., 2004). This study extends cluster theory by modeling how varying levels of congruous institutional logics influence regional cluster emergence.

While having studied the role of regulatory institutions, previous research has given little attention to the role of cognitive institutions on emergence of regional clusters (Fromhold-Eisebith & Eisebith, 2005). By analyzing both the regulatory and cognitive influences of institutions on regional cluster emergence, this study contributes to our current understanding of their implications for regional cluster emergence. In doing so, this study also contributes to a more robust understanding of how academics and practitioners conceive of and engage in regional cluster development. In this section, I discuss the theoretical, managerial, and public policy implications of this study.

### Theoretical Implications

The theoretical implications come primarily from the extension of cluster theory. This study extends cluster theory by incorporating an institutional logics framework to model institutional influences on cluster emergence and growth. However, there is an additional benefit resulting from new applications of institutional logics. Institutional logics are extended by moderating them with technological uncertainty and by applying them to regional clusters. Next, I address implications for regional clusters and institutional logics. This is followed by a discussion of possible areas for future research.

**Implications for regional clusters.** Many researchers allude to the importance of institutional influences on clusters (Maskell, 2001) and yet they remain understudied (Fromhold-Eisebith & Eisebith, 2005; Martin & Sunley, 2006). This study narrows that gap by theoretically modeling the influence of institutional context on clusters by using an institutional logics framework. Institutional logics are well suited to filling this gap in previous research on regional clusters because they have been shown to act in geographic regions (Thornton & Ocasio, 2008).

The term, congruous institutional logics, that I develop and use, can be extended to examine the concept of regional institutional niches. Niches, where particular institutional logics are prevalent, create fecund environments to support businesses with activities that align with that the values of that institutional logic. These niches benefit from the direct and moderating effects of an institutional logic.

Using institutional logics to model institutional influences on clustering identifies three relationships. First, a congruous institutional logic directly influences clustering. Second, a congruous institutional logic, through a moderating influence, enhances the direct affects on clustering of positive externalities. Third, a congruous institutional logic's direct affect on clustering is enhanced, through a moderating affect, by technological uncertainty. This theoretically combines predictions of regional clusters

(Porter, 1990; Tallman et al., 2004) with predictions of institutional theory on the influence of technological uncertainty (DiMaggio & Powell, 1983; Martinez & Dacin, 1999).

This study finds support for a direct influence from a congruous institutional logic and the moderating influence of technological uncertainty on that direct affect. Additionally, this study finds that congruous institutional logics moderate the beneficial influence of positive technological externalities when technological uncertainty is high. Taken together, the findings emphasize the importance of technological uncertainty on institutional influences on cluster emergence.

Focusing on the context of renewable energy manufacturing and a congruous logic of pro-environmentalism, I found support for the hypotheses. However, many of the theoretical predictions and findings are applicable to other industries and their associated congruous institutional logics. The key is determining the congruous institutional logics and levels of uncertainty for the industries.

Congruous institutional logics are supportive of a cluster's business activities. The theoretical model only predicts relationships between congruous institutional logics and clustering. As such it does not predict the relationship for incongruous institutional logics and clustering. However, as long as congruous institutional logics can be identified then relationships with clustering can be predicted in other industries. For example, a regional cluster such as the diamond district in New York City could conceivably have a congruous institutional logic of family loyalty (Friedland & Alford, 1991). The model predicts a direct relationship between the presence of the congruous institutional logic and clustering. However, since this industry is very stable with low uncertainty, the congruous institutional logic will have a reduced direct influence and will not have a moderating influence.

Uncertainty is important to the theoretical model in two ways. First, uncertainty enhances the influence of institutions (Dimaggio & Powell, 1983). In the diamond district example, the direct influence of a congruous institutional logic is less important because the diamond industry is very stable. Second, the moderating influence of a congruous institutional logic increases as uncertainty increases. For example, a regional cluster in organized crime also has a congruous institutional logic of family loyalty. However, as an industry, organized crime has greater uncertainty than diamond importing and sales. As such, the model predicts a stronger direct influence and a moderating influence as well.

These direct and moderating influences can be seen through the lens of transaction cost economics. Alignment of ideology has been argued to reduce transaction costs between organizations (Ingram & Simons, 2000). A similar transaction cost reduction between organizations, or individuals and organizations is likely when their beliefs, represented by a congruous institutional logic, align with an organization's activities.

Trust between transaction partners can be a competitive advantage when it reduces transaction costs (Barney & Hansen, 1994). In a study of the electrical equipment manufacturing industry, inter-organizational trust reduced transaction costs (Zaheer, Mcevily & Perrone, 1998). In a similar study of automakers and their suppliers, trustworthiness was shown to minimize transaction costs and increase information sharing between the parties in the transaction (Dyer & Chu, 2003). Hofstede (1980) argues this is because similar belief systems enhance the processing of communicated information. Although this finding comes from international management literature, the same concept applies to the finer grained nuances of geographic regions (North, 1990).

This study fills a gap in understanding about how regional differences in non-economic sectors influence economic outcomes (Lee & Sine, 2005) by incorporating institutional logics into a cluster model. Considering a Porterian cluster model (Porter, 1990), factor conditions and demand conditions are recursive with clustered firms. Pecuniary and technological externalities have a positive feedback loop occurring with clustering. However, in examining the relationship between institutional logics and clustering, this study finds a feedback loop only in the solar models and not in the wind models. The reverse causality that is present in the solar models is very small. This is likely due to the slow rate of change for cultural-cognitive institutions (North, 1990), while factor and demand conditions can change rapidly. That slow rate of change of a regional cluster's cultural-cognitive institutional resources are an advantage because they are inimitable and non-transferrable (Barney, 1991; Wernerfelt, 1984). This enduring quality makes them subtle and important, particularly in the face of globalization pressures (Guillen, 2001). Thus making a cluster's institutional resources strategically very important. Russo (2003) supports the creation of competitive advantage when organizations achieve strategic fit with their *natural* environment. Similarly, this study has the potential to show how organizations can achieve strategic fit with their *institutional* environment.

**Implications for institutional logics.** This study used institutional logics as a theory to bridge a gap in the explanation of institutional influences by regional cluster theory. In addition to extending theory on clusters, this study extends institutional logic theory by applying it to regional clusters and by modeling the influence of technological uncertainty on logics. Although researchers have shown that institutional logics influence activities within geographical areas (Lounsbury, 2007; Marquis & Lounsbury, 2007; Thornton & Ocasio, 2008), prior to this study, institutional logics had yet to be applied to regional clusters. Integrating institutional logics into regional cluster models allows prediction of the interactions between institutional logics and externalities.

This interaction, how institutional logics enhance benefits from positive externalities, has not been previously modeled. Only one study reviewed found a moderating relationship between institutional logics and organizational activities (Thornton, 2004). In higher education publishing, Thornton (2004) found the specific logic of an editorial logic moderated organizational actions, while the universalistic logic of a market logic directly influenced organizational actions. In this study I find that a pro-environmental logic is more likely to have a moderating influence when there is greater technological uncertainty. This study extends institutional logics by identifying high uncertainty as another condition in which institutional logics has a moderating relationship on organizational activities.

Institutional logics are a newer research area, first mentioned by Friedland and Alford in 1991. To my knowledge, no research has theoretically applied the impact of technological uncertainty on the potency of institutional logics. As an instantiation of institutions (Thornton & Ocasio, 2008), it follows that uncertainty will enhance the influence of institutional logics as uncertainty also enhances the influences of institutions (DiMaggio & Powell, 1983). However, this has not been hypothesized or tested. This study modeled and hypothesized the enhancing influence of increasing technological uncertainty. The analysis strongly supports a difference in the direct influence between the congruous institutional logic variable for solar energy manufacturing clustering versus wind energy manufacturing clustering. The importance of technological uncertainty enhancing the impact of a congruous institutional logic is reinforced by the support for the moderating influence of a congruous institutional logic in the high uncertainty context of solar energy.

**Future research.** This study found strong support for the idea that technological uncertainty enhances the influence of institutions on clustering. An area for future research is an examination of how other types of uncertainty influence clustering. This study focused on the influence of a congruous institutional logic on clustering. Other areas for future research include how variations in institutional logics influence clustering. Extensions of the data provide another area for future research.

This study finds that when technology is uncertain, institutional logics have a strong moderating influence on clustering. Most of the recent research on clusters has focused on the technological externality of knowledge spillover (Owen-Smith & Powell, 2004; Saxenian, 1994; Tallman et al., 2004). Future research should consider how different types of uncertainty influence other institutional influences on clustering. For example, in times of high unemployment during a market contraction, do congruous institutional logics then significantly enhance the benefits from positive pecuniary externalities, such as labor pooling, on clustering? When the type of uncertainty matches an input, the uncertainty enhances institutional influences on that business activity. This is because the additional legitimacy provided by institutions is an important source of information for decision makers navigating uncertain decisions. It would be useful to confirm if other types of uncertainty enhance the influence of institutional logics on organizational actions.

This study focused on a single institutional logic, pro-environmentalism, but organizations operate in multiple institutional spheres (Kraatz & Block, 2008). How do overlaying institutional logics influence clustering? Future research could examine how multiple institutional logics (Kraatz & Block, 2008; Thornton & Ocasio, 2008) interact with uncertainty and externalities. Since we know that congruous institutional logics influence clustering, how does more than one congruous institutional logic influence clustering? Is this influence summative or multiplicative? What if the plural institutions are contradictory? How does that influence clustering? Mars and Lounsbury (2009) argue that a hybrid logic can be created from competing logics that can open new entrepreneurial opportunities. Future research could test this proposition.

It would be interesting to study if a saturation point exists for an institutional logic at which it creates an institutional identity for clusters, just as Romanelli and Khessina (2005) have discussed the existence of a regional industrial identity. They find that it is only with a certain concentration and intensity that an industry creates an industrial identity. Just as a regional industrial identity attracts outside organizations and resources, perhaps a regional institutional identity could do the same. Haveman and Rao (1997) found co-evolution of organizations and institutions with the spread of Progressivism, however I find a one-directional relationship. Future research may find that the relationship between organizations and institutional logics co-evolves when institutional logics reach a saturation point.

Another area indicated for future research examines the potential results of incongruous institutions. Tan (2006) found premature ossification in a Beijing science park fostered by the Chinese government. He conjectured that it was due to a misalignment with the institutional environment. A potential study could identify fostered regional clusters and then measure the influence of an incongruous institutional logic., Or rather than examining when there is a misalignment with the institutional environment from the start, what happens when an organization's activities suddenly no longer fit with an institutional logic?

A before-and-after study of a drastic change in the perception of an industry would present an interesting way to measure the negative influence of institutional misalignment. For example, asbestos production and related products were once considered exceedingly safe, particularly for their fire- and heat-resistant properties. At one time, asbestos production would have been congruous with a protective institutional logic. Once it was determined that asbestos was damaging to humans, how were those businesses affected, given different levels of the once-congruous institutional logic? It is likely negative consequence of misalignment have a greater magnitude than beneficial consequences of alignment with the institutional environment. The additional transaction costs to organizations whose activities are censured by individuals would decrease organizational survival rates. It would be interesting to confirm the stultifying influence of misalignment is greater than the supportive influence of alignment with a congruous logic on clustering.

Data related extensions provide another avenue for future research. The timeframe for the study was sixteen years, but adding data post-1995 could provide a better understanding about the influence of national laboratories. More national laboratories than those included in this study were established after 1995. For example, the Idaho National Laboratory in Idaho Falls focuses on biofuels, the Oakridge National Laboratory in Oakridge, Tennessee focuses on bioenergy, and the Battelle Laboratory in Columbus, Ohio focuses on fuel cells. Including newer laboratories such as these could clarify the influence of national laboratories on cluster emergence. Klepper's (2007) study of Detroit's automotive cluster found it was the result of spin-offs. However, to know if renewable energy manufacturing clustering is due to technology demonstration leading to opportunity recognition by entrepreneurs or from labor spillover from the national laboratories will require data that are more granular. Adding more recent years to the dataset allows current interviews to capture the mechanisms in these emerging clusters.

These areas for future research result from the extension of cluster and institutional logics theories. Theoretical implications for this study extend theories on regional clusters by implementing institutional influences directly, and by moderating the direct effects of externalities. Institutional logics theory is extended by applying it to regional clusters and by modeling the influence of technological uncertainty on institutional logics. Next, I discuss how these theoretical implications influence managerial applications.

## Managerial Implications

By including institutional influences on cluster emergence, this study builds a new perspective for managers. Findings from previous cluster research indicate that managers need to consider an industry's essential and unique inputs before deciding which are most influential to the selection of a location. This study's findings, that congruous institutional logics have direct and moderating influences on the clustering of firms, encourages mangers to objectively consider the institutional environment when selecting locations for competitive advantage. Based on this study, the more uncertainty involved in the business proposition, industry, or application, the more the importance of the institutional context is increased.

This study finds a small direct impact of a congruous institutional logic on clustering. As suggested in previous research, managers must look for access to pecuniary and technological externalities. This study argues that managers also must consider institutional resources. Institutional resources that should be considered include a positive regulatory climate and a positive cultural-cognitive climate. Regulatory institutions can decrease cost of inputs or increase demand (Rosenthal & Strange, 2007). Cultural-cognitive institutions can reduce transactions costs (Ingram & Simons, 2000) and help secure resources through institutional grooming (Chiles et al., 2004). For example, consider firms that emphasize Christian values and that generate consumer goods. Locating in MSAs with a prevalence of a Christian institutional logic can create a competitive advantage for those firms.

This study finds that the direct influence of a congruous institutional logic is greater as technological uncertainty increases. The direct influence was greater for solar energy manufacturing than for wind energy manufacturing clusters because there was greater technological uncertainty with solar energy technology. For example, the direct influence of a congruous institutional logic on hydropower is less than on tidal power because the technology and markets for hydropower are well established, while the technology for tidal power is still developing. Therefore, a manager making a location decision for a tidal power manufacturing firm must be more cognizant of institutional context.

In addition to a direct influence, the findings show that congruous logics have a moderating influence in the solar models. Given the large practical impact of the moderating influence of congruous institutional logics, managers and entrepreneurs operating in technologically emergent areas should consider the competitive advantage of congruous institutional environments. The large moderating influence when technological uncertainty is high strongly suggests considering institutional resources when technology is new, such as with tidal power as compared to hydropower.

Applying this study's findings to the example of tidal power, first managers need to consider factor conditions. Factor conditions to consider include pecuniary externalities such as labor pooling and technological externalities such as knowledge spillover. Access to necessary inputs will greatly influence location selection. Sources for knowledge spillover include universities as well as federally funded laboratories. Since generating power from tides is at this time commercially and technologically uncertain, a manager of a firm in this industry should seek a location with support as well as necessary factor conditions. Institutional support includes regulatory and cultural-cognitive institutions. Locally supportive regulatory environments are important, in both wind and solar models, and number of state wind and solar incentives were significant for the amount of clustering. Locally supportive cultural-cognitive institutions are important as well, and could be measured by a greater prevalence of pro-environmental institutional logic. The large practical impact of the moderating influence of a congruous institutional logic on clustering when technological uncertainty is high could greatly benefit firms in emerging technological areas such as tidal power.

Another managerial implication involves firms relocating to the United States. These managers need to determine their competitive strengths, firm requirements, and level of uncertainty in their competitive space. Their first consideration is the benefits and detriments to locating in clusters. If congestion, competitive pressures, or unintended knowledge spillover is a great concern, then the firms should not try to locate in a cluster. Alcacer (2006) found more advanced cell phone manufacturers did not locate near other manufacturers. Their second consideration is the necessary inputs. Location selection must grant access to necessary inputs. Using variables from this study, managers should consider access to component manufacturers, labor pooling, underlying scientific discoveries, and a supportive regulatory and informal institutional environment. Their third consideration is the level of uncertainty in the industry. Mangers can then determine how important it is to find a congruous informal institutional environment. The greater the uncertainty, the more important it is that mangers select a location with a congruous institutional environment.

Since public policy makers are interested in attracting firms and supporting their growth, this study's findings are applicable to public policy as well. Next, I discuss how this study's findings influence public policy applications.

**Public Policy Implications**

Economic developers and others who determine and implement policy initiatives encourage regional clustering because of the clusters' benefits to local and national economies. However, top-down clusters are rarely successful (Fromhold-Eisebith & Eisebith, 2005). This study aims to provide better information for public policy makers through a more accurate representation of clusters and by modeling both regulatory and cultural-cognitive influences on clustering.

This study informs attempts to promote regional clusters by operationalizing clusters as interrelated firms. Since regional clusters are truly comprised of interrelated firms (Porter, 1998a) and not just one organizational form, this study holds hope of providing improved information. For example, this study found that being located near wind energy and solar energy generators was negatively associated with clustering of the equipment manufacturers. This is counter to predictions that clusters will locate near their informed customers, an indication of demand conditions in the Porter model (Porter, 1990). This finding suggests that public policy makers should consider the unique characteristics of industries prior to following prescriptive advice for encouraging clusters.

Additionally, there has been surprisingly little research on the interaction of organizations and institutions specific to regional clusters (Martin & Sunley, 2006). This study addresses that gap by using the theoretical framework of institutional logics to improve our understanding of regional cluster emergence. As Russo stated:

> Only by specifying the complex system of institutions, organizations, and actors can organization theorists make confident predictions about the outcomes of policy initiatives. Only then can organization theory maximize its relevance to the practice and study of public policy (2001: 83).

In other words, to adequately study the institutional effects on regional clusters, attention must be given to subtleties in the economic system itself. This study models and measures factor conditions, demand conditions, and two types of externalities, and how they interact with institutional influences. This study seeks to maximize its relevance to public policy by more accurately modeling clusters and by improving understanding about institutional influences on clustering.

In addition to institutional environment, when fostering clusters public policy makers need to consider the previously advised essential components. Access to skilled workforce and workforce development are necessary, as is knowledge spillover from sources for innovation. This study found that knowledge spillover from national laboratories was more important than spillover from university engineering research.

Since fostering cluster growth requires new firm foundings, it is important to understand that entrepreneurs see opportunities for new businesses based on their personal experiences and knowledge (Shane, 2000), therefore it is critical for regions to create avenues for potential entrepreneurs to learn about an industry or relevant technology. Perhaps national laboratories do a better job at spreading knowledge widely throughout the populace than university research does. Other mechanisms for cluster growth are labor market spillover and spin-offs.

This study's dataset ended at 1995. If it extended post-1995, we might find more national laboratories strongly influence clustering also. Alternatively, we may find the reverse relationship, national laboratories were established in locations with existing clustering. Also, post-1995 we may see more firm emergence and clustering resulting from university based knowledge spillover, particularly for solar energy, which is still exploring new technologies. Public policy makers need to consider all resources at their disposal, and if they are trying to create a more fertile environment, they should actively seek a government research facility.

From an institutional resource viewpoint, public policy makers should consider the regulatory and the cultural-cognitive environment when fostering clusters. This study reinforces the importance of the institutional conditions. Considering regulatory institutions, Tan (2006) felt that the premature ossification in a Beijing science park was due to a misalignment between the scientific, entrepreneurial technology transfer and the communist government that ran it. Previous research (Stuart & Sorenson, 2003b) has shown that California's failure to enforce non-compete clauses resulted in more new firm foundings. Flexibility for local governments in developing regulations can enhance cluster development (Zeitlin, 1995). The importance of creating an environment where employees can leave and start new businesses was reinforced by Klepper's study (2007) of Detroit, in which he found that the importance to the emergence of the auto cluster was due primarily to spin-offs from automakers by employees with innovations. Just as Sine and colleagues (Sine et al., 2005) found that regulations such as state wind incentives were important in fostering the creation of new wind energy generating facilities, this study finds that the number of wind and solar incentives foster wind energy and solar energy equipment manufacturers. Regarding regulatory institutions, public policy makers can create work force development, encourage knowledge spillover from research organizations, create an environment supportive of new firm foundings, and create regulatory incentives for specific industries.

Unfortunately, cultural-cognitive institutions are more difficult to shape because they change through human interpretation (Richerson & Boyd, 2005) and must overcome inertia (North, 1990). This study found that there was not a recursive influence from wind energy manufacturing clusters on the prevalence of a pro-environmental institutional logic. Even though a recursive relationship was found with solar energy manufacturing clusters on pro-environmental institutional logic, it was incredibly small. Rather than try to legislate, regulate, or through other means shape the cultural-cognitive environment, these findings suggest that public policy makers inventory their cultural-cognitive environment. Once they know prevalent institutional logics and how they might be waxing or waning, they should then determine if the cluster they are trying to foster is congruous.

Cultural-cognitive institutions are important to sustained regional economic advantage. While globalization, the rapid growth of international trade and investment, makes factor markets and codified knowledge highly transferable, research has shown that regional clusters maintain their inimitability (Guillen, 2001). The enduring locational advantages to firms in regional clusters are rooted in resources and capabilities that are difficult or expensive to transfer (Barney, 1991; Wernerfelt, 1984). Although many resources and capabilities are transferable, geographical, institutional, and inter-organizational contexts are not.

Successful cluster development occurs when business activities fit the institutional context. For example, Eugene, Oregon, has prevalent institutional logics such as pro-environmentalism, civic engagement, and counter-culturalism. Some of Eugene's factor and demand conditions are access to agricultural bounty, high unemployment, good transportation lanes, and access to large markets along the I-5 corridor. Even with this cursory institutional logic inventory, economic development officials should avoid trying to create a cluster of food production and processing such as present with corporate agriculture and meat processing in the Midwest (Artz, Orazem & Otto, 2007). The inherent industry conglomeration, environmental pollution, and concerns about the ethical treatment of animals would not align with Eugene's prevalent institutional logics. On the other hand, what can and has flourished in Eugene, Oregon, is a cluster of food suppliers, processors, and distributors that target the natural and organic consumer market (Tilleman, 2008). Public policy makers and economic developers are more likely to succeed in fitting their efforts to the cultural-cognitive institutional environment rather than trying to shape it. The findings of this study suggest that fitting the institutional environment is particularly important when there is great uncertainty involved in the technology or applications of the emerging cluster.

Not only are regional clusters interesting to public policy in the abstract, but also they are currently relevant within this study's concrete context of renewable energy. Renewable energy industries are a major benefactor of the current U.S. Administration's economic development efforts. Renewable energy and energy efficiency efforts received more than $80 billion in the American Recovery and Reinvestment Act that passed on

February 13, 2009 (Recovery Board, 2009). President Obama focused that investment by saying:

> So we have a choice to make. We can remain one of the world's leading importers of foreign oil, or we can make the investments that would allow us to become the world's leading exporter of renewable energy. We can let climate change continue to go unchecked, or we can help stop it. We can let the jobs of tomorrow be created abroad, or we can create those jobs right here in America and lay the foundation for lasting prosperity (Obama, March 19, 2009).

Public policy makers must consider the institutional conditions when fostering regional clusters focused on renewable energy technology. One of the reasons Fromhold-Eisebith and Eisebith (2005) conjecture that top-down fostered clusters fail more often is because they do not fit the institutional environment. Public policy makers need to consider the prevalence of pro-environmental institutional logics when fostering regional clusters around renewable energy technologies, particularly when the renewable energy technology is highly uncertain.

By developing a model to understand institutional influences on cluster emergence, I seek to make relevant information available for policy initiatives. I find congruous institutional logics to be a small but significant influence on regional cluster emergence. When technology is emergent, congruous institutional logics have a large and significant influence on regional cluster emergence.

In building a cluster model incorporating institutional influences, which includes regulatory and cultural-cognitive institutions and interrelated organizations, this study builds a more robust perspective for researchers and public policy makers to conceptualize this difficult task of fostering regional cluster emergence (Fromhold-Eisebith & Eisebith, 2005) in three ways. First, this study operationalizes regional clusters as interrelated firms, more accurately representing the types of regional clusters public policy makers ostensibly seek to foster. Second, it provides insight into the congruous institutional logics that must be considered to successfully foster regional clusters. Lastly, for public policy makers seeking to encourage renewable energy sources and industrial development within this industry, this study provides a strong empirical view into the regional institutional niches most likely to support such development.

# APPENDIX A

## SCHOOLS OF THOUGHT

Research in clusters comes from a diverse body of literature including economic geography, industrial economics, economic sociology, and organization theory. Empirical research rarely identifies which school of thought the theoretical underpinnings of the study rest on. As Newlands (2003, p.: 530) states in his discussion of competition and cooperation in cluster research "it has proved extraordinarily difficult in practice to distinguish the different theoretical approaches to clusters at an empirical level." The empirical unwieldiness of the different schools of thought necessitates a separate section in which to organize the theoretical research in clusters. To meld externalities and treatment of institutional environment with existing schools of thought, each school's assumptions about externalities and institutions is reviewed. Reviewing the different schools of thought by their approach to pecuniary and technological externalities assists in evaluating their contributions to the literature.

**Agglomeration theory** originated from Alfred Marshall (1920), focuses on the advantages to clustered firms in 'industrial districts' based on the higher levels of competition. In this sense, agglomeration theory conforms to neo-classical economics (Newlands, 2003). To this point, Marshall warned against cooperation because it would moderate competitive forces in the cluster. Marshall's externalities can be classified as pecuniary and technological (Fujita & Thisse, 1996) with a greater emphasis on pecuniary externalities. Marshall identified several mechanisms enhancing firm performance including access to firms in the value chain, and ease of formal and informal communication. The enhanced access to firms in the value chain and reduced transaction costs with ease of communication result in pecuniary externalities. With respect to technological externalities, Marshall stated, "the mysteries of the trade become no mystery, but are, as it were, in the air." In this sense, the hinted-at benefit is likely technological in nature, but overall Marshall emphasized pecuniary externalities.

Michael Porter (1990; 1998a) extended Marshall's agglomeration theory to specifically include more technological externalities. Porter emphasizes the increased innovation firms must develop in response to the heightened competition in regional clusters. This type of innovation improves organizational-level knowledge and capabilities; in other words, innovation improves the production function of the firm. Additionally, the common background of clustered firms provides knowledge that is a competitive advantage to the firms. Originally, Porter focused on the genesis of advantages arising from the increased competition, not cooperation. These competitively derived advantages include increasing productivity, increasing capacity for innovation, and stimulating new business ventures. In his 1998 article, Porter extended his definition to include institutions that compete as well as cooperate (:197). In summary, innovation is addressed by agglomeration theory by the need to innovate given the increased competition and aided by tacit knowledge resident in a common labor pool (Piore & Sabel, 1984).

Porter increases the applicability of agglomeration theory by adding supporting institutions to the model. However, it still does not address institutions as informal constraints, such as from interactions with regional residents or other firms in the cluster. Agglomeration theory proposes that firm advantages result from increased competition and common labor markets. While agglomeration theory focuses on explaining the performance advantages to firms in existing clusters, it does not address how clusters emerge or die.

**The California school** earned its name because the initiating researchers, Storper and Scott, were both doing research in California during the development of this literature. It tries to explain the reason for regional clusters by helping to understand the structures and understandings that enable increased communication and trust, which result in reduced transaction costs (Scott & Storper, 1986; Storper, 1995). Increasing communication and trust, and decreasing geographical distance reduces the cost of certain transactions particularly those requiring tacit knowledge. The California school relies on the advantages inherent in shared background knowledge while adding in the concept of reduced transaction costs between organizations. In this sense, the California school emphasizes pecuniary externalities because it leads to reductions in costs of inputs or increases in demand for outputs.

**Untraded interdependencies** developed from the California school's original focus on reduced transaction costs resulting from propinquity. Untraded interdependencies require close contact within the network of firms and individuals because they are the languages, understandings, rules, and technological spillovers that ease the sharing of knowledge (Storper, 1995). Untraded interdependencies, as a school of thought, explains technological externalities. This deviates from Williamsonian transaction cost economics because it incorporates the need for institutional arrangements to facilitate the development of trust and common understandings. Whereas Williamson (1991, p.: 269) purposefully excludes institutional arrangements such as customs and politics.

Storper (1995) explains the persistence of clusters because of the enduring nature of untraded interdependencies. Although a regional cluster originally formed to minimize transaction costs between firms for production factors, after transaction cost advantages for production factors shift, a cluster endures because of its untraded interdependencies. Untraded interdependencies aid cluster persistence despite loss of economic advantages. It appears this concept of untraded interdependencies is closely related to a region's informal institutions such as culture or ideology. True to technological externalities, innovation results from sharing of information through informal channels. However, the treatment of institutions is incomplete because the school of thought focuses on inter-organizational dependencies, not accounting for how other informal institutions affect organizational development.

**Innovative milieu** researchers argue that informal social interaction and a regionally mobile labor force create a process of collective learning for clustered firms (Camagni, 1991). Clearly, innovative milieu researchers are referring to technological externalities created in regional clusters. However, innovative milieu has been criticized for being underdeveloped and circular in its logic (Storper, 1995). Bringing in the concept of collective identity is a possible solution to the circular logic of innovative milieu. Brown and Duguid (2001) show how people in a community of practice, which is enhanced with collocation, develop shared identities through which communication of tacit and explicit knowledge is freely shared. Although still developing, these ideas contribute toward a broader theory of knowledge as applied to regional clusters.

**Knowledge theory** argues regional clusters exist because development of knowledge is the key competitive concern of many firms. Knowledge theory proposes that a geographically bound region in combinations with social embeddedness creates shared understandings that facilitate transfer of knowledge and enhances innovation. Clearly, knowledge theory researchers are focusing on technological externalities created in regional clusters.

In a thought provoking article, Maskell (2001) argues for two levels of information sharing and knowledge creation based on an organization's position in its value chain. Maskell suggests innovation occurs when collocated competing firms generate knowledge that is subsequently synthesized by firms vertically located on the value chain.

Tallman, Jenkins, Henry, and Pinch (2004) bring the ideas of many researchers, including Maskell, together in a cohesive knowledge theory for clusters. Tallman and colleagues propose two types of knowledge in clusters, architectural and stock. Architectural knowledge resides in the understandings of the social and industrial context as has been shown by other researchers (Almeida & Kogut, 1999; Kogut, 2000), while stock knowledge is mobile Architectural knowledge facilitates the transfer of stock knowledge. How easily the stock knowledge transfers depend on its nature, tacit or explicit, and the absorptive capacity of the firms receiving the knowledge.

Tallman and colleagues argue that firms benefit from knowledge present in a regional cluster when they are members in the geographical identity and share common interests. In other words, to develop architectural knowledge, organizations must fit the identity of the cluster. Clearly institutions are important, although they are hinted at rather than specifically addressed. While knowledge theory does not specifically address cluster emergence, Maskell (2001) addresses the growth of clusters through the mechanisms of 1) expanding existing firms, 2) relocating firms, and 3) spin-offs from local firms. The enduring and complex nature of architectural knowledge may be the result of the complex and path dependent nature of cluster development.

**Evolutionary economics** (Martin & Sunley, 2006; Nelson & Winter, 1982) applies evolutionary concepts to economic change. Although it primarily focuses on the internal workings of organizations, with a fundamental unit of the routine analogous to the biological gene, the theory includes the concept of organizational adaptation to the external environment. With its emphasis on learning and passing along of routines, evolutionary economics focuses on technological externalities created in regional clusters. Dosi, Nelson, and Winter emphasized that individuals are essential to organizational actions because they constitute organizational behaviors (Dosi, Nelson & Winter, 2000). As such, individuals' interpretations of institutions affect organizational actions, thus allowing for the interaction of organizations and institutions in the theory.

It is important to clarify evolutionary economics does not equate external environment with institutions in its terminology. Rather, evolutionary economics refers to institutions within organizations, such that their term 'institutions' is very similar to rules or routines. Organizations with less successful processes wither while those with more successful processes flourish. The concept of institutions more commonly used by researchers (North, 1990; Scott, 2001) are part of evolutionary economics conception of the external environment. A great contribution from Nelson and Winter's theory is the emphasis on change across time. This allows organizations to adapt to their external environment, an external environment that includes institutions. Evolutionary economics accounts for the emergence of regional clusters by new firms spinning-off older firms (Martin & Sunley, 2006). Successful firms have better routines to pass along to their offspring, and often the offspring firms emerge to use improved routines that could not be utilized in a parent firm (Klepper, 2007).

Clearly, no theoretical school completely deals with both technological and pecuniary externalities while at the same time dealing with formal and informal institutions. To accurately represent the interaction of institutions with technological and pecuniary externalities a theoretical framework must represent institutions as both formal rules and informal constraints.

# APPENDIX B

## SYSTEM COMPONENTS

Wind Generator System Components, listed in table 15.

Source: Sterzinger, G., & Svrcek, M. (2004). *Wind Turbine Development: Location of Manufacturing Activity*: Renewable Energy Policy Project. Pg. 10

Solar Generator System Components, listed in table 16.

Source: Sterzinger, G., & Svrcek, M. (2005). *Solar PV Development: Location of Economic Activity*: Renewable Energy Policy Project. Pg. 14

**Table 15.** Wind System Components

| Component | Sub component | NAICS 6-digit | Code description | NACIS 10-digit | Code description |
|---|---|---|---|---|---|
| Rotor | Blade | 326199 | All other Plastics Products | A141 | Other fabricated fiberglass and reinforced products |
| | Blade Extender | 331511 | Iron Foundries | 1116 | Ductile iron fittings 14 in. or more |
| | Hub | 331511 | Iron Foundries | 3221 | Other ductile iron casting for all other uses |
| | Pitch Drive | 335312 | Motors and Generators | 30 | Integral horsepower motors and generators other than for land transportation equip. (746 watts or more) |
| Nacelle and Controls | Anemometer | 334519 | Measuring and Controlling Devices | 7025 | Other meteorological instruments and parts |
| | Brakes | 333613 | Power Transmission Equip. | 3111 | Friction-type Clutches and Brakes |
| | Controller | 334418 | Printed circuits and electronics assemblies | A015 | Industrial process control board assemblies |
| | Cooling Fan | 333412 | Industrial and Commercial fans and blowers | 04 | Axial fans |
| | Nacelle Case | 326199 | All other Plastics Products | A141 | Other fabricated fiberglass and reinforced products |
| | Nacelle Frame | 331511 | Iron Foundries | 3221 | Other ductile iron casting for all other uses |
| | Sensors | 334519 | Measuring and Controlling Devices | 7 | Commercial, Meteorological, Geophysical, and General Purpose Instruments |
| | Yaw Drive | 335312 | Motors and Generators | 30 | Integral horsepower motors and generators other than for land transportation equip. (746 watts or more) |
| Gearbox and Drive Train | Bearings | 332991 | Ball and Roller Bearings | 3032 | Tapered roller bearings (including cups and cones), unmounted |
| | | | | 1023 | Complete ball bearings, unmounted, annular, including self~aligning, ground or precision, angular contact, precision |
| | Coupling | 333613 | Power Transmission Equip. | 3329 | Non-gear-type flexible couplings |
| | Gearbox | 333612 | Speed Change, Industrial | 7438 | Enclosed concentric and parallel (Planetary) center distance 6 in. or more |
| | High and low speed shafts | 333613 | Power Transmission Equip. | 3792 | Mechanical power transmission equipment, NEC, except parts |
| Generator and Power Electronics | Generator | 333611 | Turbines, and Turbine Generators, and Turbine Generator Sets | 0871 | Turbine generators |
| | Power Electronics | 335999 | Electronic Equipment and Components, NEC | 3219 | Other rectifying(power conversion) apparatus, except for electronic circuitry |
| Tower | Tower | 332312 | Fabricated Structural Metal | 5106 | Fabricated structural iron and steel for transmission towers, radio antenna, and supporting structures |
| | Tower Flange | 331511 | Iron Foundries | 116 | Ductile iron fittings 14 in. or more |

**Table 16.** Solar System Components

| Component | Sub component | NAICS 6-digit | Code description | NACIS 10-digit | Code description |
|---|---|---|---|---|---|
| Module | Complete Module | 334413 | Semiconductors and Related Devices | -A010 | Photovoltaic modules |
| | Solar Cell | 334413 | Semiconductors and Related Devices | -A005 | Solar Cells |
| | Top Surface | 327211 | Flat Glass | -1041 | Flat glass, nonautomotive, other than pyrolytically coated, clear, less than 5.0 mm thick |
| | Encapsulant | 325211 | Plastic Material and Resin Manufacturing | -1160 | Other thermoplastic resins and plastics materials |
| | Rear Layer | 326113 | Unlaminated Plastics Film and Sheet Manufacturing | -0453 | Other unlaminated plastics film and sheet |
| | Electrical Connections | 335931 | Current-Carrying Wiring Device Manufacturing | -7100 | Current-carrying metal contacts, including precious metal |
| | Frame | 332322 | Sheet Metal Work Manufacturing | -G331 | Other aluminum sheet metal work |
| Balance of System | Batteries | 335911 | Storage Batteries | -4207 | All other lead acid storage batteries, larger than BCI dimensional size group 8D (1.5 cu ft or .042 cu m and smaller), including starting, lighting, and ignition |
| | Blocking Diode | 334413 | Semiconductors and Related Devices | -7015 | Semiconductor rectifiers - power diodes and assemblies |
| | Charge Controller | 335999 | Electronic Equipment and Components, NEC | -3104 | Semiconductor battery chargers, industrial and railroad |
| | Circuit Breaker | 335313 | Switchgear and Switchboard Apparatus Manufacturing | -1100 | Power circuit breakers, all voltages |
| | Inverter | 335999 | Electronic Equipment and Components, NEC | -3219 | Other rectifying (power conversion) apparatus (except for electronic circuitry) |
| | Meter | 334515 | Instrument Manufacturing for Measuring and Testing Electricity and Electrical Signals | -1105 | Integrating instruments, electrical, demand meters, kW and kVA, combined watt-hour and demand meters (single phase and polyphase), and combined watt-hour and time switch meters |
| | Switch Gear | 335313 | Switchgear and Switchboard Apparatus Manufacturing | -A100 | Switchgear, except ducts and relays |
| | Wiring | 331422 | Copper Wire (Except Mechanical) Drawing | -4213 | Insulated copper wire and cable for electrical transmission, made in plants that draw wire |

# APPENDIX C

# THOMAS REGISTER PRODUCT CATEGORIES

## Wind Cluster Product Categories

- Windmills
- Wind Powered Generators
- Airfoils
- Nacelles
- Anenometers
- Indictors: Wind
- Windmill Towers

## Solar and Photovoltaic Cluster Product Categories

- Cells: Solar Energy
- Cells: Photovoltaic
- Photovoltaic Systems & Equipment
- Solar Electricity
- Solar Energy Controls
- Solar Energy Generators
- Solar Energy Measurements
- Solar Tracking Equipment
- Solar Energy Electric Generation Equipment
- Solar Energy Power Supplies
- Solar Power Distribution Systems
- Solar Power System Cathodic Protection
- PV Generator
- PV Booster

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