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9 Organizational Dynamics in Industrial Ecosystems: Insights from Organizational Theory

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INTRODUCTION

Industrial ecology's strength, as a theoretical and practical approach, is its attention to systemic interactions between organizations and the natural environment itself (Graedel and Allenby 1995). The metaphor of sustainable natural ecosystems provides a vision for the transformation of industrial production through optimizing the flow of materials and energy at the local, regional, and global scale (Chertow 2000; Korhonen, et al. 2004). This perspective has shifted attention away from improving or optimizing the immediate environmental impact of a single facility, as typically demanded by pollution prevention and other traditional environmental management approaches, towards a more holistic view of the company as a part of a larger network of exchanges. This physical network, however, must also be understood as embedded within a social system that influences individual and organizational action, which in turn critically contributes to the development and dynamics of industrial ecosystems.

This chapter presents three important and inter-related perspectives in organizational theory - institutional theory, field theory, and social network theory – that together shed light on the organizational dynamics inherent in and critical to the development of industrial ecosystems. Within the social science literature, these theories provide a language and set of conceptual tools for holistically analyzing the formal and informal influences of the broader social environment on a company, its possible actions within this environment, and associated outcomes. Such an understanding also sheds light on the constraints and opportunities that individual decision makers face and enables a better understanding of agents' behavior, whether that of individuals or organizations, in bringing about the changes that industrial ecology demands.

Understanding organizational action is particularly important for the approach to industrial ecology known as industrial symbiosis. In industrial symbiosis, companies physically exchange materials, energy, water, and by-products to realize net environmental and economic gains (Chertow 2000). Critical to industrial symbiosis is collaboration between disparate companies, who may share only relative geographic proximity. Empirical accounts point to numerous non-technical reasons for the failure of industrial symbiosis efforts, including failures of communication, coordination, trust, and reciprocity (Heeres, et al. 2004; Gibbs et al. 2005) as well as numerous explanations for successes, including effective brokering, education, repeated interactions, and learning over time (Baas, et al. 2004; Chertow, et al. 2005; Ehrenfeld and Chertow 2002; Jacobsen 2005; Malmborg 2004). All of these reasons are rooted in the social behaviors and interactions of individuals and organizations. Indeed, scholars have called for greater attention to the "social side" of industrial ecology, suggesting that understanding individual, organizational, and interorganizational behaviors are critical to understanding how industrial ecosystems emerge and develop (Andrews 2001; Ehrenfeld 2000, 2004; Hoffman 2003; Korhonen, et al. 2004). Several researchers have begun to draw directly from organizational theory, including institutional theory and social network theory to analyze and interpret particular examples of industrial symbiosis and industrial ecology (Baas, et al. 2004; Jacobsen 2005; Malmborg 2004). Despite this, there is no comprehensive effort to lay out concepts and tools from the social sciences for assessing the dynamics of industrial ecosystems.

At many levels of analysis, parallels exist between the concepts and tools currently prevalent within the field of industrial ecology and those introduced here. First, at the conceptual or metaphorical level, industrial ecology "requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle, from virgin materials, to finished material, to component, to product, to obsolete product, and to ultimate disposal" (Graedel and Allenby 1995: 9). Similarly, attention to the social side of industrial ecology must also embrace an "open systems" view as articulated in the social sciences, which sees organizations and their actions as embedded in and, at least partially defined by, their external environments (Hoffman 2003). Second, research on industrial symbiosis in particular finds that specific organizational, local, and regional characteristics make a difference to how the systemic influences are felt and acted upon, resulting in a variety of symbiotic configurations and approaches (Chertow 2000; Heeres, et al. 2004). Similarly, institutional theory and field theory draw attention on the social side to the various configurations of corporate behavior that emerge within an open system, and provide explanations for why, within such configurations, individual companies have different incentives and opportunities to act on industrial ecology issues. Finally, industrial ecology has the tools of materials flow analysis and life cycle analysis at its disposal (Graedel 1998; Korhonen, et al. 2004) to map and optimize linkages between individual organizations. The analogous tool in the social sciences is social network analysis – which allows for the mapping and analysis of interorganizational social linkages. Table 9.1 summarizes these parallels.

Table 9.1 Parallels between industrial ecology concepts and tools and those within organization theory

	Industrial Ecology Concepts and Tools	**Organizational Theory Concepts and Tools**
Conceptual/ Metaphorical Image	Systemic flows of material/ energy between industrial organizations Metaphor of sustainable natural ecosystem	"Open systems" view of organizations – organizational action inherently shaped by interactions with other organizations and broader society
Configurations of Industrial Ecosystems	Empirical attention to local, regional, and national factors that contribute to particular configurations Empirical attention to the development/ emergence of linkages	Field theory characterizes relevant organizational fields and the institutional norms operating within them Social and cultural capital explain who can take actions within fields, and how fields might evolve
Analytic Tools to Map/Optimize Linkages and Exchanges	Materials flow analysis, Life Cycle Analysis (LCA)	Social network analysis

Institutional theory, the theory of fields, and network theory, when taken together, can produce a robust, holistic approach to analyzing organizational dynamics within industrial ecosystems and understanding how individual and company choices shape the development of industrial ecosystems over time. The next section briefly reviews these organizational theories. We begin with institutional theory and field theory which focus on how social systems shape opportunity and action for individual organizations. Following this, we introduce social network analysis which can be used to probe particular configurations of organizational arrangements. Throughout, examples from the industrial symbiosis literature are used to illustrate how insights from these organizational theories can complement and extend current industrial ecosystem analyses. Finally, this chapter concludes with an outline of some productive directions for exploiting insights from these theories to develop a better understanding of the behavioral aspects of industrial ecology.

ORGANIZATIONAL THEORY AND SOCIAL SYSTEMS

A long standing debate within organizational theory concerns the question of whether an organization's social context constrains its managers' choices and actions, or whether managers freely chart courses of action for their organizations. Mirroring a similar debate within sociology, Astley and Van de Ven stated that one perspective "views individual action as the derivative of the social system, and the other views the social system as the derivative of individual action" (1983: 251). Many scholars see neither extreme of "structure" nor "agency" as adequate to explain the actions of organizations and regard both as important.

Institutional theory

Institutional theory recognizes the interplay of social structure and individual agency, making it well suited to exploring the social and organizational dynamics of industrial ecosystems. Institutional theory attends to the social norms that shape organizational action, and to how organizations and individuals can purposefully reshape these social norms over time (Greenwood, et al. 2002; Lawrence 1999; Maguire, et al. 2004). The term "institution" refers to often tacit, taken-for-granted norms or "rules of the game" that shape organizational and individual behavior. Formally defined, institutions "consist of cognitive, normative, and regulative structures and activities that provide stability and meaning to social behavior" (Scott 1995: 33). Less formally, institutions are "rules, norms and beliefs that describe reality for the organization, explaining what is and what is not, what can be acted upon and what cannot" (Hoffman 1999: 351).

This understanding of institutions sheds light on empirical observations that industrial ecosystem interactions only "make sense" to a limited number of companies because they go against the norms for what constitutes "business as usual" in a number of contexts (Chertow 2000; Ehrenfeld and Gertler 1997; Heeres, et al. 2004). Chertow observes that "even explaining industrial symbiosis – the educational component – is arduous because industrial symbiosis is not business as usual, and requires a significant change to dominant, rugged individualist mental models" (2000: 332). Institutional theory provides a framework for understanding such mental models not just as individual perspectives, but as products of a number of broader social forces. The influencing forces likely include the particular regulatory climate for business, the historical trajectory of industrial interactions within a country or region, the contribution of communities, local authorities or other outsiders to business decision making, and the financial and economic pressures that shape how companies' actions are valued and over what time period.

Institutional norms and organizational fields

Institutional norms have meaning for a collective of organizations and individuals who comprise a relevant organizational "field." A field is "a community of organizations that partakes of a common meaning system and whose participants interact more frequently and fatefully with one another than with actors outside of the field" (Scott 1995: 56). In contrast to an industry, a field may include regulators, pressure groups, communities, and/or businesses engaged in quite different activities. Any given organization is typically subject to many institutional norms, and is a member of many fields. For example, members of an industrial ecosystem will continue to operate in a field defined by their industry; they will still interact with their suppliers, distributors, customers, and competitors. However, these firms will also need to interact within a new field, one that may include members of local and regional government agencies, local industries, businesses operating in other sectors, environmental advocacy groups, and community organizations (Heeres, et al. 2004).

Fields take on different forms (Maguire, et al. 2004). Some fields are mature or stable with dominant actors and strongly held institutional norms (Greenwood, et al. 2002). Other fields, where norms and relationships are in flux, are considered emerging or fragmented (Fligstein 1997). There is likely much greater uncertainty surrounding what constitutes acceptable action in emerging and fragmented fields precisely because the norms are not well defined. Finally, mature fields may be "in crisis." Previously stable relationships and norms are sharply disrupted in fields in crisis (Hensmans 2003; Maguire, et al. 2004) and need to be re-established to the satisfaction of many groups within and outside the field. For example, following the Bhopal toxic gas release in the mid-1980's, the chemical industry faced a major loss of public confidence that ultimately led to the reconfiguration of its interactions with communities, regulators, and suppliers.

The development of industrial ecosystems often calls for fundamentally new arrangements which may involve companies acting outside their traditional fields. As Heeres, et al. observed, the exchanges demanded by industrial ecology involve "new *unexpected connections between heterogeneous classes of industries* or even outside industrial production" (2004: 987, emphasis in original). Reluctance to get involved in industrial symbiosis arrangements or eco-industrial parks reflects the uncertainty surrounding environmental and economic gains in such newly emerging fields (Chertow, et al. 2005; Heeres et al. 2004). Norms of engagement must be actively worked out as relationships between organizations are themselves developed within industrial ecosystems. For example, firms from different industries who share no prior relationships will need to develop norms surrounding the sharing of confidential operational information such as manufacturing plans or details on material and energy consumption.

On the other hand, when prior shared norms exist, they may enable interaction and collaboration. Local business associations have been found to be important to the development of industrial symbiosis projects (Chertow, et al. 2005; Ehrenfeld and Chertow 2002; Jacobsen 2005). Membership in such associations likely provides at least the initial contours of a field for interaction. For example, in the By-Product Synergy Project in Tampico, Mexico, 18 of the 21 participating organizations were already involved in the local industry association, thus already operating in a common organizational field (Chertow 2000). This arrangement likely facilitated the 13 early industrial symbiosis projects at the site. In cases where a nascent local or regional field exists, establishing industrial symbiotic linkages is less a question of "making" a new field and its associated norms, and more one of extending the existing field to include new types of interactions and associated norms.

In each type of field – mature, emerging, fragmented, or 'in crisis' – the strategies and skills individual organizations use to shape the field and influence or perpetuate norms will be quite different (Fligstein 1997, 2001; Rao, et al. 2000). Those seeking change need to identify the type of institutional norms that are influential, the fields in which they operate, and the type of fields that the relevant organizations are embedded in. This knowledge then enables an understanding of the opportunities, uncertainties, and risks that are present for companies seeking to depart from "business as usual" in a given setting.

Agency within organizational fields

Attention to institutional norms and fields reminds us that any organization's actions are constrained - there is not an infinite range of choices available, nor are choices determined solely by internal organizational factors. Yet, while institutional norms constrain organizational choice, they do not determine it. Early institutionalists argued that conformance with institutional norms led to isomorphism (DiMaggio and Powell 1983), resulting in members of a given field looking and acting like one another (Tolbert and Zucker 1983). More recent institutional research, however, attends to the more active role organizations play in creating and changing institutional norms through contestation, negotiation, and debate (Fligstein 2001; Greenwood, et al. 2002; Lawrence 1999; Maguire, et al. 2004). The role of institutional change - or the reshaping of rules and norms - is no longer only attributed to government (DiMaggio 1991) or social movement organizations (Benford and Snow 2000), but increasingly to organizations themselves as they strategically and purposively pursue their own agendas (Fligstein 2001; Lawrence 1999).

Institutional entrepreneurs are organizations or individuals who possess or gain the resources and social skills to influence a field in a way to realize their own interests (DiMaggio 1988; Fligstein 2001; Maguire, et al. 2004). An important empirical observation is that some actors are more successful than others at bringing about institutional change (Howard-Grenville, et al. 2007; Maguire, et al. 2004). Especially within emerging fields, effective institutional entrepreneurs are capable of bringing together disparate interests, connecting the "old" institutional logics with new ones and embedding these logics within ongoing practices (Maguire, et al. 2004). As individual or organizational actors, they work with persistence, accumulating "small wins" over time and building on these to demonstrate to others the value of the new approaches or arrangements (Creed, et al. 2002; Reay, et al. 2005).

Which organizations and individuals are best able to act as institutional entrepreneurs? This question is important for industrial ecology because for change to occur some organizations and individuals must act as early change agents, enabling the wider adoption of key practices like industrial symbiosis. Change agents, or institutional entrepreneurs, differ from others in a field because they hold greater power and influence. Power need not be simply economic or market clout, however. Social theorists think of power as having many facets and use the label "capital" to refer to multiple potential sources of power. Capital "represents a power over the field (at a given moment)" (Bourdieu 1985: 724) and may include cultural, economic, and/or social forms. Each form of capital represents a type of asset that an organization may hold, accumulate, and use over time. Although capital can be used to influence action, not all types of capital are equally valuable for doing so. For example, economic capital may not easily convert into the necessary cultural capital, which is often acquired slowly over time as an organization builds up trust and respect from others in the field.

Particularly important to the development of a number of local or regional industrial ecosystems have been the non-economic forms of capital (i.e., cultural and social capital) held by key members of the field. For example, the emergence of the Kalundborg industrial ecosystem is attributed to the "short mental distance" between participants (a form of cultural capital) and the enabling social connections (a form of social capital) achieved through the Rotary Club (Ehrenfeld and Gertler 1997; Jacobsen 2005). When initiators or participants in industrial symbiosis projects do not possess capital that others value, they will be ineffective at bringing others on board and ensuring their participation. For example, local government agencies provided funding for a number of US eco-industrial parks, but companies were reluctant to participate because they did not see the agencies as trusting partners (Heeres, et al. 2004). In this case, economic capital that government agencies provided could not substitute for necessary cultural or social capital.

This example also nicely illustrates the strong connections between institutional norms and capital. What gives particular capital value (or not) within a given field are the institutional norms operating within that field. In the US example (Heeres, et al. 2004), companies tended to value corporate anchor tenants over regulatory agencies. This preference is likely due to the broader institutional norm of government regulators as enforcers of inflexible, "command and control" style environmental regulation. This type of environmental regulation tends to limit the incentives for individual companies to innovate or cooperate with government agencies around environmental solutions, or to share "internal" information as necessary for environmental collaborations such as industrial symbiosis (Chertow 2000; Ehrenfeld and Chertow 2002; Ehrenfeld and Gertler 1997; Porter and Linde 1999). In Europe, however, a historically more collaborative relationship between organizations and regulatory agencies has shaped institutional norms where firms regard local agencies as more helpful in bringing together corporate partners in eco-industrial parks (Heeres, et al. 2004).

To understand the operation of capital, particularly social capital, in producing (or not producing) successful configurations for industrial ecosystems, it is necessary to turn to network analysis as a conceptual tool for focusing on interorganizational interactions within and across fields. Social capital is the "sum of resources… that accrue to an [actor] by virtue of possessing a durable network of… relationships of mutual acquaintance and recognition" (Bourdieu and Wacquant 1992: 119). As it exists inherently through network relationships, further understanding social capital demands a more detailed understanding of social networks themselves.

Social network theory

A network describes the web of relationships existing between a set of individual or organizational actors. More formally, "a network is a metaphor to characterize a form of economic organization in which organizations have…permeable boundaries, and numerous connections to other organizations" (Smith-Doerr and Powell 2005: 380). Of course, the image of a network is prevalent in research on industrial ecology, primarily as applied to material and resource exchanges within industrial ecosystems. Such exchanges, however, are simply one set of formal connections existing between organizations. Social network analysis draws attention to the fact that "beneath most formal ties…lies a sea of informal relations" (Powell, et al. 1996: 120). It is through these informal interorganizational relations that norms of action, reciprocity, and trust – the bedrock of social capital – develop. Social network theory and the analytic techniques of social network analysis (SNA) offer powerful ways of visualizing, analyzing, and comparing network structures and relationships across industrial ecosystems, and within the same industrial ecosystem over time. Using SNA, it is possible to identify the organizations (or individuals) who are more or less well connected within a network and make predictions about their capacity to act as change agents. SNA also enables visualization and analysis of the whole network and its evolution over time.

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Network structure and dynamics

Social networks are conceptualized in two primary ways. The first conceptualization focuses on individual ties between network actors, and the second on aggregate relationships comprising the overall network. Tables 9.2 and 9.3 summarize a number of basic social network concepts discussed below. First, ties refer to connections that exist between two focal entities (individuals or organizations). For the purposes of this chapter, organizations are the primary entity of interest. Formal ties refer to interorganizational connections that are explicitly defined and agreed to, such as a contractual arrangement (e.g., supply chain relationships). Informal ties refer to the less structured connections between organizations, which may include common membership in professional associations, or simply friendships between individuals in different organizations. It is typically through informal ties, rather than formal ones, that norms of trust and reciprocity develop over time (Uzzi 1996). Further, formal ties often grown out of preexisting informal ties (Powell, et al. 1996; Uzzi 1996; Kilduff and Tsai 2003). For example, the "short mental distance" described as essential to the development of the Kalundborg industrial ecosystem (Ehrenfeld and Gertler 1997; Jacobsen 2005) suggests that informal ties existed between managers which facilitated early, formal industrial symbiosis exchanges.

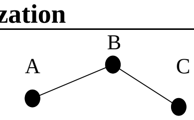
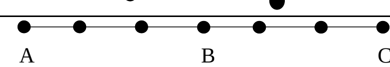
Table 9.2 *Network attribute definitions*

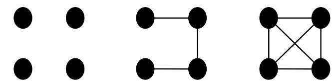
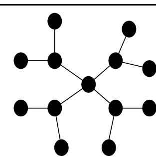
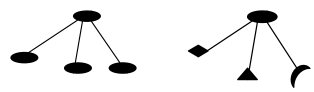
Attribute	**Definition**
Formal tie	Explicit connection between organizations in which information, goods and/or services are exchanged.

Informal tie	Tacit, social connection between members of organizations, which develops prior to or in tandem with formal ties.
Direct tie	A direct connection between two organizations.
Indirect tie	A connection between two organizations through a common third party, when the two organizations are not directly connected.
Path Length	A count of the number of steps required to connect two organizations in a network.
Density	The proportion of actual ties in a network relative to the total possible number of ties.
Centrality	How closely tied (directly or indirectly) an organization is to all other organizations in a network.
Diversity	Variety of types of organizations within a network.

When two organizations share a direct tie to each other, it means they interact directly with each other (e.g., a direct supplier-customer relationship, industrial symbiosis project collaboration). When organizations share an indirect tie, they interact only via an intermediary organization (e.g., through a third-party "broker"). When examining indirect ties, it is also useful to consider path length – the number of others separating two organizations within a network. An easy way to understand path length is through the popular notion of "six degrees of separation" which captures the maximum number of ties posited to exist between any members of a social community. For organizations with direct ties, path length is one. When there is one organization between the two focal organizations, then path length equals two, and so forth. Organizations with direct ties and/or shorter path lengths are more likely to work together than those with longer path lengths and/or no ties at all (Kilduff and Tsai 2003; Uzzi 1996).

Table 9.3 Network concepts, explanations, and visualizations

	Visualization
Direct & Indirect Ties: A and C have direct ties to B; A and C are indirectly tied to each through B.	
Path Length: A to B = 3; A to C = 6.	

Density: From left to right, density increases from completely unconnected to partially connected to fully connected networks.	
Centrality: This network has one central organization (in the middle), and four surrounding organizations with less centrality, which are connected to the remaining organizations on the periphery.	
Diversity: Despite identical structures, the network on the right has greater diversity than the one of the left because it connects different types of organizations.	

The second way to view a network is through the aggregate relationships of the organizations involved, shedding light on the structure of the network itself and the relative power, or capital, of individual organizations within it. Two network level measures, density and centrality, show complementary dimensions of the level of connectedness between organizations in a network. Density describes how closely connected all organizations in a network are to each other, by measuring the ratio of actual interorganizational ties to the maximum potential ties in the network (if every organization was connected to every other). Although higher density networks tend to have stronger norms of action and reciprocity, organizations are often more insulated from external changes than are those in lower density networks. As a result, high density networks are regarded as less adaptable. The second measure, centrality, describes how much of a network's density is organized around one or a few focal organizations. Centrality measures the ratio of the number of ties each organization has to the total number of ties in the network (Scott 2000). Central organizations, because of their higher proportion of ties, tend to have greater information flow from and influence on the network than organizations with less centrality (Powell, et al. 1996; Smith-Doerr and Powell 2005). Industrial ecosystems with higher network density would be expected to have a larger number of symbiotic exchanges, and firms with higher centrality may serve as important "anchors" (Chertow 2000; Heeres, et al 2004), enabling the flow of information, materials, resources, or "know-how" to link less connected companies. Diversity, another network-level attribute, describes the variety of the types of organizations within a network. For example, a network might be considered more diverse if it includes companies from multiple industries, small and large size companies, public and not-for-profit organizations, and/or single site firms along with facilities run by multinational parents. Overall, because diverse networks are more likely to expose organizations to different ways of interpreting issues and operating, organizations within them tend to be better at learning, creating new knowledge, and adapting to the external changes than those in homogeneous networks (Boons and Berends 2001; Goerzen and Beamish 2005; Powell, et al. 1996). This suggests that network diversity may be an important consideration for the resilience of an industrial ecosystem as it develops over time

Embeddedness and collaboration

Organizations within networks often share multiple ties and multiple types of ties. Equally important as the structure of these ties are the nature, strength, duration, and overlap of the various relationships. As the number and type of ties between organizations increase over time, the organizations are said to become increasingly "embedded." Embedded organizations are more likely to interact with each other, rather than with other organizations, even when economic considerations do not necessarily justify such interactions (Uzzi 1996). Given that industrial symbiosis projects often require organizations with little or no prior history to collaborate on projects whose economic justifications may be ambiguous (Ehrenfeld and Gertler 1997), embeddedness is likely an important attribute of many interorganizational relationships in successful industrial symbiosis arrangements.

At least three aspects of embeddedness influence the extent and nature of collaborations between organizations. First, embeddedness increases interorganizational trust, potentially decreasing the cost of working together in the future (Uzzi 1996). Second, embeddedness increases information sharing. Organizations with embedded relationships are more likely to share necessary project information, even when it is sensitive in nature. As information sharing increases, the information is also perceived as more credible and valuable to those receiving it because it is coming from a trusted partnership. Finally, embeddedness increases joint problem solving. This stems directly from the previous two points – trust increases information sharing, which in turn also broadens the perspectives of the organizations involved. Overall, joint problem solving tends to increase organization-level learning, performance, and adaptability (Boons and Berends 2001; Powell, et al. 1996, Uzzi 1996).

These findings from the social networks literature support many of the empirical observations of those who study industrial symbiosis and industrial ecosystems. Prior research on industrial ecosystems shows trust, communication, and collaborative problem solving as keys to success (Baas, et al. 2004; Ehrenfeld and Gertler 1997). Boons and Berends (2001) also suggest that the value of increased information sharing is further enhanced when sharing occurs within a heterogeneous, or diverse, network. For the particularly complex technical, operational, economic, social and regulatory problems encountered in the development of industrial ecosystems, the collaborative problem solving enabled by embedded network relationships also increases the chances of finding novel solutions amenable to all parties (Baas, et al. 2004; Ehrenfeld and Gertler 1997).

IMPLICATIONS

To understand the emergence and development of industrial ecosystems, a robust, holistic understanding of the social systems in which individuals and organizations act must exist. Organizational and individual agents often need to change their current perspectives and relationships, implying changes in institutional norms and associated configurations of organizational fields. Furthermore, some agents will be more successful at bringing about intended changes than others. The language of capital and social networks allows researchers and practitioners to understand what gives rise to these differences and to identify characteristics of agents and broader social systems that enable the development and resilience of industrial ecosystems. Several important implications for research and practice follow.

Agent-based modeling of organizational interactions

Individual managers and companies as a whole are agents whose decisions and actions critically shape whether and how industrial ecosystems emerge and develop. Social network analysis can be used to systematically analyze relationships within industrial ecosystems and compare relationships across several industrial ecosystems or within a single ecosystem over time. It provides a powerful way of representing the relative position and power, or capital, of various agents within the ecosystem, and for observing and predicting consequences of change over time.

Some of the specific questions social network analysis can help answer include: How does the centrality of certain agents within an industrial ecosystem network influence the adoption of material exchanges or resource sharing arrangements? What role do preexisting ties between agents play in the development of an industrial ecosystem and/or the emergence of particular exchanges? While social network analysis can capture the position of, and opportunities available to, agents, it must be enhanced by an understanding of broader institutional norms and the nature of particular ties in order to qualitatively assess the meaning of various network relationships and understand why and how they arose in a particular social context. For example, a highly central organization may posses certain types of capital, enabling it to exercise power over others in the network. The types of capital and their value, however, must be determined empirically and not simply assumed from a centrality measure.

Brokering in industrial ecosystems

The findings from the organizational theories discussed suggest it is difficult to develop new, collaborative arrangements between companies with no preexisting relationships; and that it takes time and repeated interactions to develop new norms supporting such arrangements (Uzzi 1996; Lawrence, et al. 2002, Smith-Doerr and Powell 2005). In these settings, third party brokers, who facilitate introductions between organizations who previously did not know one another, may be particularly important. Although the term broker *per se* is not prominent in the industrial ecology literature (see Malmborg 2004 for an exception), researchers have suggested the value of local associations, anchor tenants, and local champions in drawing organizations together in industrial ecosystems (Gibbs 2001; Baas, et al. 2004; Chertow, et al. 2005; Heeres, et al. 2004). Yet successful brokering is not merely about making connections. To be successful, the organizations involved must feel that the connections made are relevant and valuable (Burt 2002) and these organizations must trust the broker (Granovetter 1985). Finally, the broker must understand the context in which the brokering is taking place (Bourdieu 1986).

Brokering takes different forms, with some brokers acting as passive conduits of information and others much more actively involved in transactions (Andrews and Mauer 2001). A distinction is drawn between information brokering, in which a third party collects and disseminates information to others, and relationship brokering in which the third party seeks to understand more deeply the needs of two companies, working with them to identify and implement appropriate solutions. While both are likely helpful in the development of industrial ecosystems, the latter may result in more robust, meaningful, and strongly embedded ties between companies.

Several specific questions arise regarding the role and effectiveness of brokers (who may be individual or organizational agents) in influencing the organizational dynamics in an industrial ecosystem. For example, does the presence of a broker change the structure and operation of an organizational network? Under what social and organizational conditions are information and/or relationship brokering valuable? How does the role of the broker change over time as the network structure and nature of relationships change? Social network analysis in combination with analyses of the institutional and field conditions can address these questions.

Development of industrial ecosystems over time

Finally, the organizational theories discussed here make predictions about how organizational arrangements will change over time in industrial ecosystems, in response to the decisions and actions of particular individual and organizational agents. Mapping network structure over time, and seeing how ties between organizations change and evolve, can capture the organizational dynamics of the industrial ecosystem. Interesting questions include: What factors influence the nature and speed of change in interorganizational relationships within industrial ecosystems? How are the development of interorganizational ties fostered by the absence or presence of various types of brokers, regulatory incentives, economic conditions, and/or preexisting ties in emerging industrial ecosystems?

These questions carry important practical implications. The most prominent model of an industrial ecosystem is Kalundborg, Denmark, which developed organically over about four decades. Given today's pressing environmental needs, the prevailing opinion is that industrial ecosystems need to develop more quickly than this. However, as Ehrenfeld and Gertler (1997: 77) cautioned, "designing an industrial ecosystem from the ground up is different and cannot follow the evolutionary path that contributed so strongly to Kalundborg's positive development." Planned industrial ecosystems are often less effective than anticipated (Baas, et al. 2004; Heeres, et al. 2004; Gibbs et al 2005), suggesting that a middle ground between unassisted emergence and full planning is needed. Indeed, empirical research suggests that successful arrangements often grow from small projects, expanding in scope and participation over time as new projects prove successful (Baas, et al. 2004; Chertow 2000; Ehrenfeld and Gertler 1997). These findings fit well with the organizational theories outlined in this chapter, suggesting the value such theories can bring to informing and analyzing the development of industrial ecosystems.

CONCLUSION

There is considerable potential for insights from organizational theories - such as institutional theory, field theory, and social network theory, - to contribute to a more holistic understanding of the social and organizational dynamics of industrial ecosystems. As Cohen-Rosenthal (2000: 245) observed, "knowledge of kinds of waste streams can provide a means to determine potential linkages. But this does not link them; decisions by people do." This chapter has argued for paying attention to social and organizational factors that shape people's decisions on these crucial matters. By attending to institutional norms and the fields and networks in which they operate, industrial ecology researchers can unite the long-held view of industrial facilities as embedded within systems of material and resource flows with a view of them as also embedded in systems of social interactions Both perspectives need attention in order to understand and influence the development of robust industrial ecosystems.

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