HOW CORE AND PERIPHERAL COMMUNITIES SHAPE THE BOUNDARIES OF AN EMERGING FIELD

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ABSTRACT

Understanding how the boundaries of a field form and shift over time is a central question in institutional theory. Field formation is rarely the work of one actor alone, yet few theories explain how multiple communities shape the emergence of a field’s social and symbolic boundaries. Through an in-depth longitudinal study of the nanotechnology field, I show how initially core communities (i.e. futurists and government officials) that identified strongly with the field, expanded field boundaries, increasing the field’s legitimacy and resources. The availability of these resources attracted peripheral communities (i.e. service providers, entrepreneurs and scientists) that identified weakly with the field, to claim membership with the field and expand the field’s symbolic boundary. The expansion of both the social and symbolic boundaries of the field, threatened core communities’ identity and their access to field resources. Core communities responded by restricting the definition of the field in order to contract the symbolic boundary and policing membership in order to contract the social boundary. By focusing on the contested actions of core and peripheral communities, this research provides a dynamic explanation of how communities differ in their roles and effects on the formation of an emerging field’s social and symbolic boundaries.
INTRODUCTION

Understanding the emergence of the boundaries of a field is a central question in institutional theory. Some scholars have focused on the social boundary—that is, “objectified forms of social differences” or who is considered a member of the field (Lamont and Molnar, 2002: 168). These studies have shown how the social boundary of a field is challenged and maintained (Greenwood and Suddaby, 2006; Zietsma and Lawrence, 2010) and how disparate parties successfully work across social boundaries (O’Mahony and Bechky, 2008). Studying the social boundary scholars have also shown that when participants self-claim membership in a field or are defined as members by others the social boundary of the field might expand (Wry, Lounsbury, and Glynn, 2011; Granqvist, Grodal, and Woolley, 2013).

Other scholars have studied the symbolic boundary or what defines belonging to the field. Scholars have shown how the symbolic boundaries might expand when participants re-define the field (Lawrence, 1999; Pachucki, Pendergrass, and Lamont, 2006; Suddaby and Greenwood, 2005). For example, challenges to the definition of what constituted “modern architecture” expanded the boundary of which buildings architects referred to as “modern” (Jones et al., 2012). Scholars have also shown that field activists might sharpen the symbolic boundary of a field by contrasting it with other fields (Weber, Heinze, and DeSoucey, 2008). While this work has provided important insights into the emergence of the social and symbolic boundaries of fields separately less is known about the interrelationship between the emergence of a field’s social and symbolic boundaries (Lamont and Molnar, 2002; Hoffman, 1999).

Scholars lack of focus on the interrelationship between the social and symbolic boundaries during field emergence is surprising given that when participants in early fields try to judge who belongs to a field they need a criteria for what makes these potential participants alike. Indeed, “the operation of bringing together different [people] must be justified with reference to a
principle of equivalence which clarifies what they have in common” (Boltanski and Thevenot, 1999: 361). For example, determining who is an organic farmer necessitates defining what is meant by “organic” (Lee, 2009). Likewise, early members might want to define legitimate and resourceful outsiders as part of the field, even if that might entail expanding the definition of the field in order to do so (Wry, Lounsbury, and Glynn, 2011). Considering the interrelationship between the social and the symbolic boundary is particularly important in emerging fields, because both who and what are part of the field is likely to evolve and be contested as the field expands (Aldrich and Fiol, 1994; Kaplan and Tripsas, 2008; Santos and Eisenhardt, 2009).

Understanding how the social and symbolic boundaries of fields co-evolve necessitates a deeper understanding of who drives boundary dynamics. Fields consist of multiple communities that “in the aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services or products” (DiMaggio and Powell, 1983: 148; Wry et al., 2010). How these communities influence field boundaries is shaped by their degree of identification with the field that is the degree to which community members believe field-defining attributes also define the community (see Dutton, Dukerich, and Harquail, 1994; Glynn, 2008; Lawrence and Suddaby, 2006). An important albeit often overlooked aspect of fields is that some communities participate in multiple fields simultaneously (Seo and Creed, 2002; Wenger, 1998). As a consequence, communities differ in the degree to which they identify with any given field (Glynn, 2008). This variation separates core communities that identify strongly with the field from peripheral communities that do not (Lave and Wenger, 1991; Cattani, Ferriani, and Allison, 2014).

Acknowledging that fields consist of core and peripheral communities matters (Wry et al. 2010). Field participants from different communities are differently situated in terms of what is at stake in the emerging field (Lawrence, 2004; Glynn, 2008). For example, peripheral communities may wish to expand the field’s symbolic boundary to define more outsiders as part of the field in order to see the field grow. In contrast, core communities whose identities are invested in the
status quo are likely to revolt against such efforts to change the field’s symbolic boundary. Furthermore, peripheral communities’ attempts to self-claim membership in the field might grant them access to the monetary and cultural resources of the field, leaving less for the core communities (Lamont and Molnar, 2002). Because fields are sites for attainment of material and cultural resources, we can only understand boundary emergence in light of such contestations over these resources (Lawrence and Suddaby, 2006; Zietsma and Lawrence, 2010).

Although communities vary with regards to what is at stake when field boundaries change, institutional theories have primarily focused on core communities when explaining field emergence. Weber, Heinze, and DeSoucey (2008), for example, show how dedicated cattle ranchers attempted to stimulate more farmers to join the field of grass-fed cattle by changing the meaning of “grass-fed” production. However, the authors do not explore what happens after the field has become legitimated and peripheral farmers, who might be less committed to the core values of grass-fed production, see opportunities (in terms of higher prices) in claiming that their meat is also “grass-fed”. Likewise, Ferraro and O’Mahony (2012) detail how programmers committed to the open software movement managed the boundaries of their projects. Yet their study does not detail the consequences of peripheral communities, like commercial start-ups or universities, self-claiming that their programs are “open source” although they might not be freely available or developed collaboratively. However, without considering the role of peripheral communities we might overlook an important element of how the social and symbolic boundaries of fields are constructed.

In particular, while these studies have provided important insights into how core communities shape the boundaries of a field, scholars have left unexplored how the boundary practices of dedicated field members are dynamically related to the behavior of peripheral communities. In their review of the literature, O’Mahony and Lakhani (2011: 15) highlight the need to create a unified frame to explain how different types of communities shape the emergence of field boundaries (see also Wry, Lounsbury, and Glynn, 2011: 459; Lamont and Molnar, 2002;
Lawrence, Suddaby and Leca, 2009). For example, studies within cultural entrepreneurship, which focus on the use of cultural resources rather than boundary construction per se, have shown that peripheral communities often strategically claim membership in a field even if their activities might not fit within the symbolic boundary (Lee, 2001; Glynn and Abzug, 2002; Glynn and Marquis, 2004). Likewise peripheral communities define outsiders as part of the field—with or without their consent (Granqvist, Grodal, and Woolley, 2013). Such claims to membership might change perceptions of the field’s social boundary, thereby increasing competition for access to the field’s resources. These processes might be particularly important during field emergence before boundaries are solidified and there is still confusion about who and what should be included in the field (Kaplan and Tripsas, 2008). Given this crucial, but understudied, interaction between core and peripheral communities, examining how diverse communities dynamically shape the social and symbolic boundaries of an emerging field is critical.

To investigate this issue I conducted an in-depth longitudinal study of five distinct communities in the emerging nanotechnology field from 1984 to 2005. I show that core communities (i.e. futurists and government officials) initially expand the boundaries of the field to increase the field’s legitimacy and resources. This increase in legitimacy and resources, however, entices peripheral communities (i.e. service providers, entrepreneurs and scientists) to claim membership within the field, thus, expanding the field’s social boundary. Such claims create a self-reinforcing cycle where some peripheral communities, particularly service providers, wish to further grow the field and thus work to enlarge the definition of the field. However, this social and symbolic expansion posed a threat to the identity of the core communities and their ability to access resources, which motivated them to define the field more narrowly and then use this narrow definition to police membership claims. By focusing on the dynamic and contested actions of core and peripheral communities, this paper develops a nuanced theoretical model of the relationship between the creation of social and symbolic boundaries, divergent community interests, and conflict over a field’s resources and legitimation.
CONSTRUCTING THE SOCIAL AND SYMBOLIC BOUNDARIES OF AN EMERGING FIELD

The Social and Symbolic Boundaries of Organizational Fields

Organizational fields are a set of organizations “that partake of a common meaning system and whose participants interact more frequently and fatefully with one another than with actors outside the field” (Scott, 2000: 56). To understand the emergence of field boundaries we need to consider both a field’s symbolic and social boundary. The symbolic boundary is created through efforts to define the field, that is field participants coming to agree upon what belongs to a field. As Zerubavel (1997: 2) clarifies, “[T]he word define derives from the Latin word for boundary, which is finis. To define something is to mark its boundaries, to surround it with the mental fence that separates it from everything else.” The symbolic boundary defines those elements that can legitimately be considered a part of the field and the ones that cannot (Lamont and Molnar, 2002). As such, the symbolic boundary is the locus where groups struggle with and agree upon definitions of the field. At stake in contestations over the contours of the symbolic boundary is the field’s collective identity, “who we are” as a field (Wry, Lounsbury, and Glynn, 2011; Lawrence and Suddaby, 2006).

In contrast, the field’s social boundary determines “who is a member” of the field, dividing who is considered to belong from those who are not (Lawrence, 2004; Zietsma and Lawrence, 2010). Such social division creates a group of people who obtain the privileges and burdens of membership, including access to the field’s monetary and cultural resources, such as legitimacy, status and visibility (Lawrence and Suddaby, 2006; Lounsbury and Glynn, 2001). For example, claiming membership in a field can provide a community with funding opportunities, but also recognition as an influential voice in a new industry. If a field is considered rife with resources, multiple communities might seek to claim membership. For instance, Zbaracki (1998) show how the perceived legitimacy associated with membership in Total Quality Management
(TQM) led many firms to claim that they were engaged in TQM even if their practices diverged from standard TQM practices. Precisely because access to a field’s monetary and cultural resources is determined through field membership, the creation of social boundaries is highly contested (Holm, 1995; Zietsma and Lawrence, 2010).

The existing literature within institutional theory has made progress in studying how core communities construct either the symbolic or social boundaries of emerging fields separately. Jones et al. (2012) show how contestation among different architects about what constituted a modern building expanded the symbolic boundary of modern architecture to encompass more diverse kinds of buildings. However, while this study provides insight into the contested nature of how the symbolic boundary is formed it leaves unexplored how changes in the symbolic boundary shaped who claimed to be a “modern architect”, and how such claims in turn shaped the symbolic boundary. Likewise Hoffman (1999) details how corporate environmentalism within the US Chemical industry emerged through contested issues. Missing from this study is an understanding of how the contestation over issues and membership in the field are interrelated, and the mechanisms that drove changes within the field.

Other studies within institutional theory have focused primarily on the social boundary. Lawrence (1999) details the struggle to create the field of forensic accounting—that is investigative and fraud related accounting. During the early period the field of forensic accounting consisted primarily of a core community of boutique firms. However, as the field evolved service providers to the field began to develop their own membership rules and certifications to determine who was or was not a member in the field. This led new peripheral communities—primarily large diversified firms—to claim membership in the field. However, missing from this analysis is an understanding of how changes to the social boundary shaped the definition of the field and whether boutique firms engaged in any actions in order to counter-act the encroachment on their field and the redefinition of what it meant to be a forensic accountant. Studying the emergence of social boundaries within satellite radio and workstations respectively,
Navis and Glynn (2010) and Kennedy (2008) both show that the social boundary of fields might emerge by firms defining competitors as members of the field. Yet, these accounts do not take into consideration that not all competitors might want to be defined as members of the field or how such redefinitions shape the symbolic boundary. Similarly focusing on the social boundary Zietsma and Lawrence (2010) show how contestation around who could participate in decision processes around the British Columbia coastal forestry field ultimately led to an enlargement of the field’s social boundary. Yet, this study does not detail how these changes to the social boundary could only be achieved by redefining what it meant to be a member.

Although the literature in institutional theory has tended to study the social and symbolic boundary separately the two boundaries are inextricably related. Who can claim membership in a field depends on whether claims can be justified with regards to the dynamic and changing definition of the field (Lamont and Molnar, 2002). For example, how the field of environmental audit was defined shaped which communities could claim membership in the field (Lawrence, 2004). Thus, “symbolic boundaries can be thought of as a necessary but insufficient condition for the existence of social boundaries” (Lamont and Molnar, 2002: 169). Simultaneously, the social boundary might shape the symbolic boundary. Indeed, if new communities either self-claim membership in the field or other communities define them as members of the field, the community engaging in such social boundary expansion might have to also expand the definition of the field for these new communities to be viewed as legitimate members of the field.

In order to study the construction of the social and symbolic boundaries of an emerging field, we cannot examine them independently but need to investigate their dynamic co-evolution. Disentangling the social and symbolic boundaries and their dynamic relationship, however, is not easy (Lamont and Molar, 2002; Gieryn, 1983), because it necessitates studying claims to membership and definitions of the field by multiple communities over time. Yet failing to do so leads us to overlook the contestation that takes place when multiple communities struggle to come to agreement on a field’s boundaries and access to the field’s resources.
**Field Boundaries, Communities, and Monetary and Cultural Resources**

Fields consist of multiple communities (DiMaggio and Powell, 1983). While all the communities that constitute a field obtain part of their identity from field participation, they differ in their level of identification with the field. Core communities tend to enter the field early and focus their activities in the focal field. In turn, their identity is primarily derived from, and they identify strongly with, the focal field (Lave and Wenger, 1991; Cattani, Ferriani, and Allison, 2014; see also Dutton, Dukerich and Harquail, 1994). Any changes to how a field is conceived, thus, might impact the core identity of the community. For example, early proponents of “green-chemistry” — an effort within chemistry to improve the safety and environmental impacts of chemicals — identified strongly with the field. Challenges to the symbolic boundary of the field, therefore, became viewed as a threat to the identity of this core community, who then fought to regain control (Howard-Grenville et al., 2014).

In contrast, peripheral communities derive only a small part of their identity from the focal field, getting their main source of identity elsewhere. For example, newcomers to the field of green-chemistry from private industry or other parts of the chemistry field were not as dedicated to green-chemistry as the core community. Many of these newcomers began to publish articles self-claiming to engage in “green-chemistry” although their work did not conform to the principles — like “prevent waste” or “increase energy efficiency” — that the core community had identified as defining green-chemistry. As a consequence the core community saw their own identity and that of the entire field of green-chemistry threatened. This motivated their efforts to contract the boundary of the field (Howard-Grenville et al., 2014). Along these lines, peripheral communities may be less invested in the central activities of the field and produce products that are disliked by core communities (Cattani, Ferriani, and Allison, 2014). Indeed, because communities often participate in multiple fields at once, peripheral communities might enter and exit a particular field based on the monetary and cultural resources perceived to be associated with the field, without being dedicated to the core values and principles of the field.
Viewing the construction of field boundaries from the perspective of multiple communities opens up the question of whether boundary practices by “partially embedded group members who make their primary identities in different fields” engage in different boundary practices than members of dedicated core communities (Wry, Lounsbury, and Glynn, 2011: 459)—and whether these practices might change during field emergence.

During the early period of the field core communities might define legitimate and resourceful outsiders as part of the field with the hope that to make other stakeholders’ perceive the field as more desirable or appropriate (Wry, Lounsbury, and Glynn, 2011). Indeed, such expansion of the social boundary might also imbue the field with more resources (Kennedy, Lo and Lounsbury, 2010). For example, Lounsbury, Ventresca and Hirsch (2003) show that the social movements advocating a new approach to waste management engaged in framing activities, which expanded the social boundary by stimulating participation in recycling. By expanding its membership, this movement also increased the legitimacy and resources associated with the field. Likewise, in the field of modern architecture, early core communities attracted new resourceful participants to the field by inviting them to join the field (Jones et al., 2012).

We know less about the actions of peripheral communities, who often enter later. Some research suggests, however, that peripheral communities are more prone to engage in practices that fit poorly with the field’s symbolic boundary (Granqvist, Grodal, and Woolley, 2013). For example, organizations might change their name or that of their product to invoke references to the field in order to increase legitimacy or attract resources, despite their tangential relationship to the core activities of the field (Lee, 2001; Glynn and Abzug, 2002; Glynn and Marquis, 2004; Zhao, Ishihara, and Lounsbury, 2013). Peripheral organizations may also claim association with the field in employment ads (Zilber, 2006), press releases (Pontikes, 2012) or conferences (Granqvist, Grodal, and Woolley, 2013) to advance their own strategic interest. Taken to an extreme, such activities can expand the boundaries of the field as claims to field membership alter perceptions not just of who is a member, but also how the field is defined. Indeed, such actions
that expand field boundaries can be a call to arms for core communities who not only find the legitimacy of the field and their identity questioned, but also their access to the field’s monetary and cultural resources threatened.

The peripheral communities claims to membership in the field undermines the existing status quo (Howard-Grenville et al., 2014). Early participants in the Dogme film movement were, for example, dedicated to the core values of eliminating post-production manipulations of filmed material, but later partially embedded participants tried to relax some of these constraints thus diluting what it meant to produce a Dogme film. While less attention has been paid to this issue, Wry, Lounsbury and Glynn (2011) suggest that this social boundary expansion might entice core communities to contract the boundaries of a field in order to reclaim control over how the field is defined and who is considered a member.

In short, this body of research demonstrates the importance of understanding how communities differ in the role they play in constructing the social and symbolic boundaries of an emerging field. However, so far the literature has examined only how core communities shape the social or the symbolic boundary separately—leaving unexplained how peripheral communities contribute to the co-evolution of field boundaries. I address this question by identifying how communities within the nanotechnology field expanded and contracted the definition of the field to shape the symbolic boundary and, in turn, used this new symbolic boundary to alter who was considered a member in the field. In detailing this process I develop an integrated theoretical model of the dynamic relationship between how communities shape a field’s social and symbolic boundaries and the availability of material and symbolic resources.

**METHODS**

Inductive research is best done in settings in which the phenomenon of interest occurs in abundance (Garfinkle, 1967). Navis and Glynn (2010: 465) call for studies to be done in fields that are “more (or less) institutionalized, complex, or broad in the range of actors or scope of
activities.” While much existing research has been done in settings where field boundaries were more clearly defined by a regulatory body (see, e.g., Zietsma and Lawrence, 2010; Hoffman, 1999), research in less institutionalized settings is lacking. Considering fields with less regulatory oversight, in fact, may provide more insight into the dynamics of how both core and peripheral communities construct a field’s social and symbolic boundaries, because communities have more leeway to shape the boundaries. Indeed, peripheral communities may more easily make membership claims in less institutionalized fields, such as those that are large and heterogeneous, where no regulatory body can police such claims for their veracity.

Based on these considerations, I chose to study the nascent nanotechnology field. Nanotechnology is invisible to the naked eye and involves complex science. Such complexity and remoteness from lived experience make the field more difficult to comprehend and open to interpretation and contestation. At the same time, the nanotechnology field is large and heterogeneous involving multiple diverse communities (Granqvist and Laurila, 2011; Kaplan and Radin, 2011; Kennedy, Lo and Lounsbury, 2010).

Research Setting: The Emerging Nanotechnology Field

The National Nanotechnology Initiative describes nanotechnology as research, engineering and technology that operate at the nanometer scale (National Science and Technology Council, 2000). (One nanometer is one billionth of a meter.) Research in nano-science can be traced back to the 1950s, but the major scientific breakthroughs that led to the advancement of nano-science happened in the early 1980s (Wry and Lounsbury, 2013; Wry, Lounsbury and Jennings, 2014).

In the early 1980s, a Ph.D. student at MIT named Eric Drexler began musing about the possibility of constructing nano-scale mechanical systems that mirrored the functioning of biological organisms. Drexler called these nano-scale machines “nanotechnology.” He popularized his ideas in his 1986 book *Engines of Creation*, which generated vast interest in the popular press (Kennedy, Lo and Lounsbury, 2010). Simultaneously, research in materials science,
physics, electrical engineering, and chemistry were converging on the nano-scale. And scientists and entrepreneurs began to wonder how these discoveries could be applied to real world problems, like creating new stain resistant or water-repelling materials. Even though these technologies were far removed from Drexler’s original vision of nano-scale machines, the definition of nanotechnology expanded to include this wider array of technologies. This expansion called into question what the field’s boundaries indeed were and who would decide. (An overview of key events in the emergence of the nanotechnology field can be found in Table 1.) In the remainder of the paper I elaborate on how both core and peripheral communities contributed to the expansion of the social and symbolic boundaries of the nanotechnology field.

Data Collection

I employed a grounded-theory approach to the collection and analysis of data (Strauss and Corbin, 1994). Applying this approach, I collected four types of data: (1) ethnographic observations at conferences and networking events; (2) interviews with members of core and peripheral communities; (3) archival data from each of the five communities involved in the nanotechnology field; and (4) collection of nanotechnology definitions in the top 50 US newspapers. Table 2 provides an overview of these data. Below I discuss each type of data in greater detail.

Ethnographic observations. In order to examine how core and peripheral communities constructed the social and symbolic boundaries of the nanotechnology field, I conducted ethnographic observations at 25 nanotechnology conferences and networking events focused on the commercialization of nanotechnology during the 2003 to 2005 period. Conferences and
networking functions are major field-configuring events (see Garud, 2008; also Zilber, 2012) during which participants actively discuss, contest and negotiate the boundaries of the field. At these events, I found that opinions about who and what should be included in the field varied depending on the communities in which participants claimed membership.

In total, I identified five main communities involved in the nanotechnology field: (1) futurists, (2) government officials, (3) service providers, (4) entrepreneurs and (5) university scientists. The participants in the futurist community were followers of Eric Drexler and his non-profit organization, the Foresight Institute. Employees in congressional offices and government agencies, as well as appointees to government committees, comprised the government community. Venture capitalists, conference organizers and journalists at trade magazines comprised the community of service providers, who, although diverse in training, were united around the goal of stimulating demand for their services within the emerging nanotechnology field. The community of entrepreneurs included representatives from small and large as well as private and public firms. Researchers at universities and government research facilities comprised the community of university scientists. More information on each of the communities is provided in Table 2. I elaborate on the role of each of the communities in the rest of the paper.

Interviews. To further deepen my understanding of how communities constructed the boundaries of the nanotechnology field, I interviewed participants from each of the communities. During 2003 to 2005, I conducted 77 interviews. The initial interviewees were approached at nanotechnology conferences and networking events or were located through nanotechnology directories, and subsequent interviewees were identified using snowball sampling. Table 2 displays the distribution of interviews among the five communities involved in the field.

Archival data. To understand how the boundaries were constructed over time, I collected an extensive set of archival materials from newspapers, trade journals, press releases, newsletters and congressional records among others (see Ventresca and Mohr, 2002). I followed Hoffman’s (1999: 5) advice that studies of fields “must be located within each actor’s particular
communication and interaction channels” and Abrahamson and Eisenman’s (2008) call to study discourse longitudinally. I located communication channels that represented each of the five communities and used data from these sources to construct a dataset of articles for each community from the time the participants within the community began to talk about nano-science and until 2005 (See Appendix 1 for a description of how these data were collected.) I chose to search for articles pertaining to nano-science, which is broader than just the term “nanotechnology”, to avoid left-censoring of the data due to shifting terminologies for how to refer to the field. (Across the five databases, the search yielded 9,011 articles.) I used this larger sample in order to investigate when each community became involved in nanotechnology and how they discussed the boundaries of the field. To develop a precise understanding of the social and symbolic boundaries I considered nano-science articles that referenced nanotechnology, as well as articles, which discussed nano-science, but did not reference nanotechnology.

To create a representative sample of articles from each of the five datasets for qualitative analysis, I selected one article each month. If no article appeared in a focal month, I would search for articles in the following month and select two articles if they were available. In the early years, if less than 12 articles existed for a particular year, I included all of the articles from that year in the analysis regardless of the time of year they were published. Table 2 provides an overview of the complete set of archival data and the subsection of 938 articles that I selected for in-depth qualitative analysis. I used these five archival datasets to create a detailed longitudinal understanding of the boundary practices that each community engaged in to shape the social and symbolic boundaries of the nanotechnology field over time.

**Nanotechnology definitions.** To investigate change in the symbolic boundaries of nanotechnology over time, the last step in my data collection was to gather changing definitions of nanotechnology across time. I collected the first definition appearing in articles about nanotechnology from the top 50 US newspapers (defined by circulation) every other month per year starting from 1987, when the first definition of nanotechnology appeared, to 2005. Like
above if no definition appeared in a focal month, I would search for a definition in the following
month. This methodology generated a total of 146 definitions. I had eight coders rate how
expansive versus restrictive these definitions were on a 5-point Likert scale. A detailed
description of how the definitions were analyzed can be found in Appendix 2.

**Data Analysis**

I coded the ethnographic observations, interviews and archival data using a grounded theory-
building methodology (see Spradley, 1979). Consistent with this tradition, my analysis cycled
between deep analysis of the data, developing theoretical categories, and relating these insights to
the existing literature on social and symbolic boundaries in emerging fields. More specifically,
my coding evolved through the five stages depicted on Figure 1, which I elaborate below.

Stage 1: Creating social and symbolic boundaries. The first stage in data analysis was
open coding (see Strauss and Corbin, 1994), in which I collected all statements related to how
participants created boundaries during their interactions by providing expansive or restrictive
definitions of nanotechnology, defining new communities as members of the field or policing
other communities claims to membership. This coding began during the initial analysis of the
ethnographic observations and continued during the collection of the interviews and the archival
data in an iterative fashion. I then coded all ethnographic observations, interview segments and
archival data in which participants referred to a change in the boundaries of nanotechnology. I
found that the boundary practices were related not only to determining who was engaged in
nanotechnology but also to whether the definition of nanotechnology expanded or contracted over
time. Following Lamont and Molnar (2002), I defined who was considered as participating within
the field as an indication of social boundary formation. Likewise, I coded definitions of what
belongs to a field as the creation of a symbolic boundary. For example, I coded the statement “In
my view, we are a nanotechnology firm” an instance of who the entrepreneur considered to be engaged in nanotechnology—thus forming the social boundary. In contrast, I coded the statement by a service provider that “Nanotechnology is defined as anything that is at the nano-scale” as an example of what nanotechnology was—thus shaping the symbolic boundary.

After I had identified the boundary practices related to the construction of the field’s boundaries, I investigated these changes systematically over time. In particular, I investigated systematic changes to the social boundary by searching for the frequency with which each community used the words “nanotech” or “nanotechnology” when referring to nano-science. This analysis, thus, shows how each community changed their claims to membership in nanotechnology over time. Likewise, I measured the change in definition of nanotechnology in newspaper articles over time to detail changes in the symbolic boundary.

**Stage 2: Identifying practices related to boundary expansion and contraction.** After identifying boundary practices used to create social and symbolic distinctions, I re-examined all of these interaction sequences. Through this re-analysis, I discovered that the communities’ boundary practices were used to expand or contract the boundaries. For example, I coded the statement “I would say Mictec is a nano firm” as an expansion of the social boundary, whereas I coded “I call people out if they are not really nano” as related to a contraction of the social boundary. Likewise, I coded “We tried to define nanotechnology in a more general way” and “[the new guidelines included] a new more specific definition” as expansive or contractive practices related to the symbolic boundary.

**Stage 3: Identifying six boundary practices and their effects.** During the third stage of analysis, I followed the advice of Hedström and Swedberg (1996: 281) to “clearly explicate the social mechanisms that produce observed relationships between explanans and explanandum.” As a result of this process, I identified six boundary practices—four related to constructing the social boundary (“self-claiming,” “self-disassociating,” “other-defining,” and “other-policing”) and two related to constructing the symbolic boundary (“restricting the definition” and “enlarging the
definition”). I also identified six distinct ways these boundary practices impacted the symbolic boundary of the field—three ways that expanded the boundaries ("enlarging the definition", “other-defining”, and “self-claiming”) and three ways that contracted them ("restricting the definition”, “other-policing”, and “self-disassociating”). I elaborate on these six practices and their effects in the findings section.

**Stage 4: Identifying core and peripheral communities and their relevant boundary practices.** During the fourth stage, I categorized communities into core and peripheral communities based on whether community members believed the attributes that defined the field also defined their community (see Dutton, Dukerich and Harquail, 1994). For example, I coded the statement “the mission of the Foresight Institute has always been to advance nanotechnology” as strong identification with the field, whereas I coded the statement “I see myself primarily as a material scientist…. I only use ‘nanotech’ with funding agencies” as an example of weak identification with the field. Thus, the Foresight member would be considered a member of a core community, while the material scientist would not. I found that futurists and government officials identified strongly with the field, in turn they constituted the field’s two core communities. In contrast, I found that service providers, entrepreneurs and scientists identified weakly with the field—that is they constituted the field’s peripheral communities. Both peripheral Table 2 shows how each of the communities’ identification with the nanotechnology field separated them into core and peripheral communities, as well as how this identification impacted boundary practices.

After I had grouped the communities into core and peripheral communities I analyzed how the degree of identification with the field impacted what boundary practices members used to shape the field. I found that it was primarily peripheral communities that engaged in self-claiming and self-disassociating. Both peripheral and core communities engaged in the expansive boundary practices of enlarging the definition and other-labeling. In contrast, it was mostly the core communities, who engaged in the restrictive boundary practices of other-
policing and restricting the definition. In order to make sense of these findings I examined the temporal development of when and how each of the communities used these practices.

**Stage 5: Identifying the co-evolution of the social and the symbolic boundaries and its relationship to community involvement.** I coded the time at which each community began to participate in the nanotechnology field. Core communities entered early and developed a strong identification with the field. The peripheral communities entered later and were less dedicated to the field. More specifically I found that core communities early in the field engaged in practices to expand the social and symbolic boundaries. However, when peripheral communities became involved they expanded the boundaries even more, threatening the identity of core communities and their access to resources, thus motivating core communities to contract the boundaries.

During this analysis I identified two inflection points: The first in 1997 when peripheral communities began to self-claim membership in the field and the boundaries of the field thus increased dramatically. The second in 2000 when core communities reacted to the identity threat posed by boundary expansion by restricting the definition and using this narrower definition to police who was a member of the field. This analysis led me to identify three phases of the nanotechnology field: (1) Boundary creation: 1980s–1997, (2) Boundary expansion: 1998–2000, and (3) Attempted boundary contraction: 2001–2005. Although the phases sometimes overlapped and blurred, for the sake of exposition in the following section I discuss these phases discretely.

**HOW CORE AND PERIPHERAL COMMUNITIES CONSTRUCT THE BOUNDARIES OF AN EMERGING FIELD**

The boundary practices of the communities involved within the nanotechnology field expanded both the social and symbolic boundaries from the creation of the field in the early 1980s to the end of this study in 2005. A detailed analysis of the actions of the communities, however, reveals a more nuanced dynamic than mere expansion. In the following section, I briefly chronicle the involvement of both core and peripheral communities in the creation, expansion and contraction
of both boundaries, before I explain the mechanisms that account for these changes. I discuss each issue—community involvement, boundary changes and mechanisms—across the three phases in the emergence of the nanotechnology field.

Changes to the Boundaries of the Nanotechnology Field

From the inception of the nanotechnology field in the 1980s until 2005 when nanotechnology became a household expression, the boundary practices of core and peripheral communities expanded the definition of nanotechnology from signifying a miniature mechanical system to include any activity or technology at the nano-scale. The futurist Tim Allen,¹ who has been involved in the nanotechnology field since its emergence in the 1980s, describes this expansion, “The term “nanotechnology” of course has now been expanded … to include all sorts of things that were not part of the original definition of the technology, and to some extent there had been a parallel growth in the use of the term just to mean any nano-scale activity.” Analysis of nanotechnology definitions in use by the top 50 US newspapers details this expansion of the symbolic boundary. For example, in 1986 nanotechnology included only microscopic robots, but in 2005 the field had expanded to include any technology that was at the nanoscale. The results depicted in Figure 2 show the statistically significant expansion in the definition of nanotechnology, which encompassed a broader range of phenomena over time.

As communities enlarged the symbolic boundary of nanotechnology they also expanded the social boundary. An analysis of the archival data reveals that communities’ claims to membership in the nanotechnology field increased over time. Figure 3 shows the temporal shift in the social boundary over the study period. A closer look at how definitions of and membership in the nanotechnology field have changed over time exposes the details of this expansion.

¹ The names of the informants and their institutional affiliation have been changed for anonymity. I designed the pseudonyms to reflect the informants’ ethnicity and gender.
Phase 1: Boundary creation: 1980–1997. During the early 1980s until 1997, the futurists were the primary community in the nanotechnology field. Their definition of nanotechnology was very narrow and specific and focused on the idea that nanotechnology was a nano-scale machine or robot. During this phase, outside communities used the futurists’ definition when referencing the field. For example, a newspaper article in the *San Francisco Chronicle* from June 1989 defined nanotechnology as “using a combination of biology and computers to create microscopic ‘assembler robots’ that could build a new car or maybe a new being.”

Phase 2: Boundary expansion: 1998–2000. During the second phase, futurists expanded the definition of nanotechnology, and used this more expanded definition to define other more legitimate and resourceful communities as members of the field. The futurists were largely successful in this quest. Around 1998 government officials began to pay attention to the futurists’ descriptions of nanotechnology, and conclude that nanotechnology might be a field worth exploring. Government involvement in nanotechnology catapulted nanotechnology from fringe science to legitimate field associated with both monetary and culture resources—a process that culminated when President Bill Clinton announced the National Nanotechnology Initiative (NNI) in the year 2000 (Kennedy, Lo and Lounsbury, 2010). The hard work that many government officials put into nanotechnology and the resources that they made available to field participants meant that many government officials identified strongly with the field. In turn, government officials became a second core community within the nanotechnology field.

The blessing of the US government increased the involvement from peripheral communities. The new expanded definition of nanotechnology meant that service providers, like journalists and conference organizers, began to view nanotechnology as a hot topic, which might increase readership and drive conference attendance. The service providers identified more weakly with the nanotechnology field. They worked to expand the field definition, so that it no
longer referenced specific mechanical elements like “robot” and “machine,” and instead included any engineered technology at the nano-scale. For example, a definition of nanotechnology from *Pittsburgh Post-Gazette*, February 1999, stated that “nanotechnology is the engineering of structures at the atomic level.” The service providers thought this more expansive definition would increase demand for their service. However, this new expanded definition threatened the identity of core communities who were vested to the status quo.

**Phase 3: Attempted boundary contraction: 2001–2005.** During the third phase, more peripheral communities entered the field, thereby expanding the social boundary of nanotechnology even further. It was not until this late phase that most entrepreneurs and university scientists began to claim membership in the nanotechnology field. Echoing Gieryn’s (1983) study, however, many scientists identified more strongly with other organizational fields. With its mix of scientific disciplines and assimilation of language and imagery from science fiction, nanotechnology was not the ideal home for hard scientists (Granqvist and Laurila, 2011; Kaplan and Radin, 2011). Likewise, many entrepreneurs did not view nanotechnology as a serious commercial endeavor. Both university scientists and entrepreneurs tended to identify less with the field than the communities that had joined the field earlier.

In the beginning of this phase the core communities (e.g. futurists and government officials) tried to restrict the symbolic boundary by creating more restrictive definitions of nanotechnology to limit the claims to membership by the peripheral communities (e.g. service providers, entrepreneurs and scientists). Yet following a short contraction, efforts by the peripheral communities meant that the definitions of nanotechnology again became more inclusive. For example, the *Chicago Sun-Times* wrote in a 2005 article that “Nanotechnology [is] the science of creating things on a molecular level,” a definition that considered any technology at the molecular scale—from materials science, applied physics, chemistry, biotechnology, and electrical engineering—to be within the symbolic boundary of nanotechnology. Indeed, there were many more members of the peripheral communities then of the core communities, which
meant that it was difficult for the core communities to police all of the actions of the peripheral communities. At the end of the study period, definitions of nanotechnology focused nearly exclusively on the size of the technology.

In what follows I examine the practices of both core and peripheral communities that accounted for the expansion of the social and symbolic boundaries of the nanotechnology field and detail their interrelationship. In particular, I show that to change the symbolic boundary communities engaged in two practices: (1) enlarging the definition and (2) restricting the definition. To change the social boundary communities engaged in four practices: (1) other-defining, (2) self-claiming, (3) other-policing and (4) self-disassociating. Table 3 shows how core and peripheral communities used the six boundary practices and the effects of these practices on field boundaries. Table 4 provides an overview of how the communities used the boundary practices during each of the three phases. I include illustrative quotes of the six boundary practices throughout the paper and provide further examples in Table 5.

Communities’ Boundary Practices During the Emergence of the Nanotechnology Field

Phase 1: Boundary creation: 1980–1997. During this first phase core communities created and enlarged the symbolic boundary of the field and subsequently used this expanded definition of nanotechnology to guide the expansion of the social boundary.

*Creating and enlarging the symbolic boundary.* The futurists founded the nanotechnology field, and were thus the field’s first core community. The identity of their community was formed around stimulating and managing the growth of the field. Caroline Trucker, an early futurist, recalled that “…we were creating a group of engaged individuals—people who cared deeply about nanotechnology”. One of the first action futurists engaged in was to create the field’s symbolic boundary by defining what ought to be associated with the
nanotechnology field. In Drexler’s first book *Engines of Creation* (1986: 4–5) he wrote: “We can use the [term] ‘nanotechnology’ … to describe the new style of technology. The engineers of the new technology will build both nanocircuits and nanomachines.” That is, the futurists defined nanotechnology as the creation of nano-sized machines, electronics and robots.

Over time the futurists realized that for nanotechnology to succeed they needed to expand the definition of the field in a way that would appeal to more communities. They thus *enlarged the definition*—that is they created a definition of nanotechnology that was more inclusive of diverse interpretations. During the early 1990s the futurists wrote several books in order to expand interest in nanotechnology to other communities. Gertrud Pearson, who was involved in the writing of these books, explained:

> The readership was not attracting people coming from the non-technical side of the house, so that would be folks from business, intelligent people with a humanities background, people in law, politics…. And if what you were interested in doing was seeing the field develop, not just technically but also with a business perspective, you’re going to need to fund this thing…. So you just need to be able to open this dialogue…. So I mean [expanding the definition] was deliberately based on audience targeting.

Over the course of the early 1990s the futurists’ efforts at expanding the definition of nanotechnology became increasingly successful. By enlarging the definition to include a broader range of technologies and commercial products, futurists expanded the symbolic boundary of what could be considered nanotechnology.

*Expanding the social boundary through other-defining.* The futurists’ early attempts at expanding the symbolic boundary did not take place independently of attempts to expand the social boundary. Indeed, they used the new definition that they created to engage in *other-defining*—that is, they claimed that other communities belonged within the boundaries of nanotechnology with or without the consent of the focal community. In their second newsletter (Foresight Update 2, 1987) Drexler stated that there are many scientists “contributing to the emergence of nanotechnology—protein design, synthetic chemistry, scanning tunneling microscope technology, molecular modeling on computers—there are dozens or hundreds of
research groups, in industry and academia…so the numbers are large.” However, the futurists’ attempts to attract scientists to the field were largely unsuccessful.

The futurists also defined work that was on-going in government labs as nanotechnology in order to get the U.S. government interested in participating in nanotechnology. For example, they highlighted how some of NASA’s research within space-exploration could be summoned under the nanotechnology rubric. By the mid 1990s the futurists found a receptive audience among some government officials, who thought they needed a new way to communicate about science to generate more funding for basic research. As Christian van Kyle, a government official, explained: “The problem is, whether we like it or not, if you walk into Congress and you say, ‘chemistry,’ or you say, ‘physics,’ or you say, ‘mathematics’ to them, it says, ‘more of the same.’ And so they are looking for new and exciting things that should benefit the country, and I think the term [nanotechnology] kind of got that.” Initially, government officials did not identify strongly with nanotechnology, but as they began to spearhead and take responsibility for large initiatives related to the field, their identification with nanotechnology grew.

Futurists also defined articles and conferences written and organized by service providers as nanotechnology. The futurists found that service providers (e.g., journalists, conference organizers, consultants and lawyers) were interested in participating in the nanotechnology field. One conference organizer, Mark Jensen, explained: “We are always looking for ‘The Next Big Thing’—people want to hear about the new things that are going on. That is what drives business.” However, for many service providers, nanotechnology was but one field in which they were engaged and their identification with the nanotechnology field was therefore weak. Most service providers viewed the nanotechnology field as a fleeting opportunity—a field in which they might be involved temporarily until other opportunities presented themselves. The service providers, therefore, became a peripheral community within the nanotechnology field.

**Phase 2: Boundary expansion: 1998–2000.** During the second phase of the evolution of the field both core and peripheral communities attempted to control the symbolic and social
boundaries of nanotechnology. In particular, during this phase both service providers and
government officials created their own definitions of nanotechnology and employed these new
definitions to expand membership in the field.

*Enlarging the symbolic boundary.* Starting around 1998, the more active involvement of
service providers and government officials brought about new dynamics within the
nanotechnology field. Government officials created a definition of nanotechnology that would
work across multiple governmental agencies ranging from the Defense Advanced Research
Projects Agency (DARPA) to the National Science Foundation (NSF) to the National Institute of
Health (NIH). This new definition was more encompassing because it no longer only emphasized
only the creation of machines at the nano-scale. However, government officials maintained that
nanotechnology was not simply a technology at the nano-scale, but needed to include some
degree of control (placing atoms in specific locations).

In contrast, service providers—a peripheral community—were bolder in their attempts to
expand the definition of nanotechnology. Because service providers were less dedicated to the
nanotechnology field their main goal was to create a definition of nanotechnology, which would
make their services (such as conferences, trade magazines and legal advice) relevant to a large
number of clients. Tom Bearfield, an organizer of networking events, for example, explained that
“we used a broad definition of nanotechnology” in order not to exclude any specific technologies.
The service providers, thus, expanded the definition of nanotechnology to included activities that
firms and scientists were currently doing at the nano-scale even if they did not include any degree
of control or mechanical activity at the nano-scale.

The result was that service providers expanded the symbolic boundary beyond the
definition advocated by the core communities (e.g. futurists and government officials). This
expansion weakened the distinction between technologies that service providers were promoting
as belonging to nanotechnology and those other communities considered part of a range of
proximate fields like materials science, physics or chemistry, thus, diluting the symbolic boundary erected and tailored by the core communities.

_Social boundary expansion through other-defining_. The involvement of service providers and government officials within the nanotechnology field during the late 1990s expanded the social boundary. During this early phase there were few university scientists and entrepreneurs that self-claimed membership in the nanotechnology field. Government officials therefore defined prominent scientists and entrepreneurs as participant in the field in order to shepherd support for nanotechnology through Congress. Martin Lanchaster, CEO of a non-profit organization, explained how his organization came to be defined as belonging to the nanotechnology field:

> I do think it was useful for Congress to point to us and say, ‘Look, there’s an industrial association in existence. See, [nanotechnology] is real.’ And whether or not it was doesn’t matter, but you can say, ‘Look, it’s there, [nanotechnology] exists.’ … So to be able to show some step forward such as us—a business community—that’s a step forward. It may not be saying, ‘Look, there’s a new job,’ but at least there’s … this [nanotechnology] that isn’t just science, it’s going toward something.

In addition to making science more palatable to Congress, the involvement of the government catapulted nanotechnology from the fringe to mainstream; if the US government invested in nanotechnology there must be important scientific and economic advances to be made within the field. Sam Brown, an entrepreneur, explained, “After the government [became involved] many began to look to nanotech as the Next Big Thing. It changed things.” In particular, the legitimacy of the field increased when the US government enacted the National Nanotechnology Initiative (NNI), which earmarked federal research dollars for nanotechnology.

In contrast to the core communities’ efforts at other-defining the actions of the service providers were more expansive. Service providers needed to identify companies and university scientists that could be showcased at conferences and written about in magazines. For example, one CEO, Carl Yin explained that he did not consider his company to belong to the nanotechnology field even though conference organizers kept defining his firm as such:
This idea [that nanotechnology] is things that are smaller than a hundred nanometers, that by virtue of those dimensions produce novel physical properties—that’s not what we’re doing at all. But there we are, lumped into nanotechnology. Neither we nor XynTinic [another company presenting at the conference] are really nanotechnology by that definition.

In particular, service providers tried to involve successful entrepreneurs and scientists like Carl Yin that would make their conferences and journal articles attractive to their customers.

**Social boundary expansion through self-claiming.** During the late 1990s the legitimating effect of the involvement of the US government and the activities of service providers enticed peripheral communities (e.g., scientist and entrepreneurs, who had their primary identity in other fields like physics, materials science, or chemistry) to join the field, albeit at first only slowly. During this phase the social boundary of nanotechnology expanded not only through other-defining but also through self-claiming—i.e., potential participants claiming membership in the field. For example, a photovoltaic researcher, Mike Levine, had throughout his entire academic career referenced his work as “materials science” or “photovoltaics.” But after the government legitimated the nanotechnology field, he began to refer to his work as “nanotechnology.”

Many participants within the field noted the explosive claims to membership in nanotechnology. For example, the Chief of the Nano-Science Division of a large defense company, Bill Moore, complained how competitors used the word “nanotechnology” to describe their products even though they did not fit within the symbolic boundary: “Unfortunately, I think “nano” has become misused. Anything that seems to be smaller than the normal product line they call nano, like nano-switches as big as your watch. It’s ridiculous.” Others echoed Moore’s sentiment. For example, a venture capitalist, Kurt Weisman, who controlled a dedicated nanotechnology fund, said most claims to nanotechnology were just people renaming their existing work. He said that he had “even seen people lately who are working with complex molecules that say they are nanotechnology”—that is, people doing basic chemistry claiming that their work is nanotechnology.
These claims were both motivated by access to funding, but also to cultural resources in the form of visibility and increased reputation. An entrepreneur, Peter Fritz, explained that “there are many who take advantage of the buzz around nano. If you say you are nano people pay attention.” Using irony to respond to such claims while also taking advantage of the buzz, the American Chemical Association used the following slogan to advertise its 2005 annual conference: “What is a nine letter word for nanotechnology? ‘Chemistry’.” Such rampant claims to membership by peripheral communities accelerated the expansion of the social boundary and increased the discrepancy between how core communities defined the field and who was claiming membership in it.

**Phase 3: Attempted boundary contraction: 2001–2005.** Increased claims to membership by peripheral communities did not leave the symbolic boundary unaffected. Peripheral communities’ rampant claims to membership meant that initially the social boundary of the nanotechnology field expanded more rapidly than its symbolic boundary. The expansion of the social boundary motivated service providers to expand their definition of nanotechnology in order to create a more encompassing boundary definition that could account for all the novel claims of the new members. With a new definition of the field in hand, even more members of the peripheral communities began to claim membership in the field accelerating the expansion of the social boundary. The expansion of the social boundary, thus, created incentives for service providers to further expand the symbolic boundary.

The enlargement of the symbolic boundary fueled the expansion of the social boundary, because an enlarged definition made it easier for peripheral communities to use the novel definition to justify their membership. Indeed, this expansion of the social and the symbolic boundary suggests a self-propelling dynamic powered by the legitimacy and resources associated with the field. Michael Larsen, a founder of one of the largest conferences on nanotechnology, explained how expansion of the social and symbolic boundaries were mutually reinforcing:
I think there was a kind of self-fulfilling definition, which came about through “Here’s the funding for it.” So when you have the funding for nanotech you’ve got all these people sitting around saying, “Can I get that funding? If I can, that means I’m nano.” So there was a scrambling of name changes in academia—materials science departments or electrical engineering departments five years ago saying, “I’m nano.” And when they say they’re nano they now define “That’s nano.” And then you have all of the industrial sectors and industrial societies that said, “Within our communities now we’re going to do a nano-conference or we’re going to do a nano-publication. Here’s what’s in it.” So the American Physical Society or the Market Research Society, or us—we all said, “Here’s how we define [nanotechnology].” And in the process, all of their constituents said, “Oh, okay, look, I’m nano now.”

As Larsen notes, peripheral communities increasingly self-claimed membership in nanotechnology to obtain the monetary and cultural resources associated with the field.

However, this escalating dynamic between the expansion of the symbolic and the social boundary meant that contradictions arose at several levels. On one hand, many of the novel claims to membership by the peripheral communities did not fit within the symbolic boundary creating a discrepancy between the social and the symbolic boundary of the field. The existence of these contradictions undermined the legitimacy of the nanotechnology field as participants inside and outside the field began to question its substance. Elena Markow, a material scientist who had been working on nanostructures throughout her career, for example, stated: “[Nanotechnology] is so broad that there is no coherence, and it is so broad that [scientists who claim they are working on nanotechnology] are not developing a specific technology.”

On the other hand, contradictions arose between the core and peripheral communities’ understanding of the symbolic boundary. While core communities favored a restrictive symbolic boundary that preserved their identity, peripheral communities were eager to expand the symbolic boundary in order to claim membership. An entrepreneur, John Milininski, explained, “basically, if you look at the nanotechnology area there are, depending on who you talk to … a lot of different perceptions of what it is, and in some cases they don’t match up or don’t even overlap.”

Restricting the symbolic boundary. At stake with the expansion of the symbolic boundary was the collective identity of the field. Changes in the collective identity threatened the identity of
the core communities. Allan Mortensen, a futurist, explained that “now when we say we are dedicated to developing the future of nanotechnology people think its about stain-resistant pants and windshield wipers. That is not nanotech…that is not what we do!” The expansion of the symbolic boundary, thus, motivated core communities to begin restricting the definition of nanotechnology as a way to curtail self-claiming and other-defining. *Restricting the definition* involved creating a definition that excluded technologies from the field.

The futurists tried to restrict the definition by referring back to how nanotechnology was defined in the beginning of the field. In 2004, Drexler lamented the new, expanded definition of nanotechnology, for example:

> Although now used more broadly, the term nanotechnology has been used since the mid-1980s to label a vision [that] … projects the development of nanomachines able to build [other] nanomachines and other products with atom-by-atom control…. [Instead the new] expansive, scale-defined nanotechnology includes what had been termed thin films, fine fibers, colloidal particles, large molecules, fine-grained materials, submicron lithography, and so on…. Any connection between this miscellany of technologies and a research program inspired by the [futurist] vision is almost imperceptible.

Likewise for government officials, the expansion of the symbolic boundary was also problematic. As the symbolic boundary of the field expanded, government officials began to worry about losing control of the definition of nanotechnology and thereby both control over the flow of resources and the direction of the field that they had helped to create. A government official, Anne Palmer, explained their efforts to restrict the definition:

> [Nanotechnology] does have a definition, and we spent quite a bit of time on it…. So I think there’s a general agreement that nanotechnology is not just small but rather is small with the incorporation of some performance or property because of its size. The third thing is the idea of control—that there’s sort of an engineered or designed quality. It’s not just collecting pollen samples that happen to be nanometer size. That’s just not a nanotechnology project!

Palmer further explained that within the government there was intense debate about specifying the symbolic boundaries of nanotechnology. Government officials wanted to create a more specific definition of nanotechnology that could be used to exclude scientists who claimed that part of their activity was at the nano-scale even though it was not innovative or transformative.
Restricting the definition of nanotechnology was an important tool for core communities to limit claims to membership by the peripheral communities. Because the peripheral communities were large (there were many more service providers, scientists and entrepreneurs than there were futurists and government officials), however, practices that expanded the field’s boundaries were more widespread than restricting practices. As a result, the symbolic boundary of nanotechnology kept expanding despite the core communities’ efforts to the contrary.

*Contracting the social boundary through other-policing.* At stake with regards to the social boundary of nanotechnology was access to the monetary and cultural resources associated with the field. The expansion of the social boundary meant that core communities had to fight for resources together with the peripheral communities. For example, when the government began working towards the creation of the National Nanotechnology Initiative (NNI), futurists had eagerly been anticipating the flow of resources to their causes. Yet because peripheral communities were also claiming membership in nanotechnology, resources were being diverted elsewhere. Drexler (2004) explained:

One would expect that the NNI, funded through appeals to the [futurists’] vision, would focus on research supporting this strategic goal. The goal of atom-by-atom control would motivate studies of nanomachines able to guide molecular assembly…. In the course of a broad marshaling of resources, at least one NNI-sponsored meeting would have invited at least one talk on prospects for implementing the [futurists’] vision. The actual situation has been quite different. No NNI-sponsored meeting has yet included a talk on implementing the [futurists’] vision.

Futurists saw themselves as the creators of the nanotechnology field, but they now had to share the attention around nanotechnology with many other communities. Indeed, because many peripheral communities were now claiming membership in nanotechnology, futurists had to fight to even be seen as relevant to the development of the field.

To limit such claims, core communities engaged in *other-policing.* Other-policing relies on “enforcement, auditing, and monitoring” the actions of participants (Lawrence and Suddaby, 2006: 231). In particular, other-policing involves the repudiation of others’ claim to membership
in the field. Government officials policed membership claims when deciding which proposals to fund. As Brigitte Albany, an employee at the Environmental Protection Agency who was sorting through applications for their call for nanotechnology proposals, explained: “The application asks what the topic area is and poses some sample questions, and occasionally there are some people who cannot read directions [by submitting things that are not nanotechnology]. But you just throw those out.” Albany stressed that when making funding decisions, her government agency sorted through proposals to determine which conformed to their definition of nanotechnology.

Core communities engaged in other-policing to counter the other-defining and self-claiming practices of peripheral communities. In the case of nanotechnology, core communities’ attempts at other-policing did curtail the expansion of the social boundary. They were not able, however, to police all self-claiming and other-defining activities engaged in by peripheral communities, which tended to be greater in number and larger in size than core communities. Furthermore, because there was no central venue where membership claims had to be made, core communities lacked regulatory authority to police all claims.

*Contracting the social boundary through self-disassociating.* Although many potential peripheral members were still claiming membership in the field during the third phase of field’s evolution, scientists and entrepreneurs, who were prominent within their respective fields, began to worry that the dilution of nanotechnology’s boundaries undermined the legitimacy of the field. These successful entrepreneurs and scientists had access to other sources of funding and could, therefore, *self-disassociate* from the field—that is actively distance themselves or their firms from the field (see also Granqvist, Grodal, and Woolley, 2013). For example, the founder and CEO of the successful company FazLigt, Gabriel Watson described an instance when his firm was included within the nanotechnology field by a conference organizer, despite his reservations:

I remember the first time. We got invited to this conference called the Nanotech Capital Conference. And I said to our VP of marketing at that time, “I really don’t know that we want to be associated with this stuff, honestly.” I don’t think we want to be affiliated with nanotech. This stuff is just too diffuse, too weird. I don’t think we want to categorize ourselves that way. And he said, “you know,
that’s fine, let’s go present anyway, you know, I’m curious. So our VP of marketing went out there, presented at the Nanotech Capital Conference, which was organized by a couple of big banks. And they gave awards to the five nanotechnology companies most likely to succeed, and FazLigt was one of them. And then my VP of marketing said, “Wait, actually I didn’t mean to win.”

Due to the other-defining practices of service providers, which sought to bring him into the fold to increase their legitimacy, Watson struggled to keep his company from being included within the nanotechnology field. FazLigt was a successful company, and because their technology was close to the nano-scale, many service providers who were working in or writing about nanotechnology included FazLigt on their lists of successful nanotechnology firms. Thus, Watson often had to explicitly state that FazLigt was not a nanotechnology firm. Mark Ryland, CEO of Bendtex, was in a similar situation. He explained that many stakeholders included Bendtex as part of the nanotechnology field, but that he refused this membership: “No, no, no! I don’t [position Bendtex as a nanotech company]. Some people put us in that category and the truth is ‘nah.’”

This disassociation from the nanotechnology field by the most prominent scientists and entrepreneurs contributed to the loss of legitimacy for the field, as claims to membership increasingly were done by less successful firms that fit weakly with the symbolic boundary. However, it was difficult for many participants to keep track of exactly how they were being labeled. As a consequence, self-disassociating tended to be less widespread than other-defining practices, which increased the number of scientists and firms—willingly or not—that were considered part of the nanotechnology field. This process, combined with the continued widespread self-claiming by many within the peripheral communities, facilitated the continued expansion and dilution of the social boundary.

**Theoretical Model: How Core and Peripheral Communities Shape the Social and Symbolic Boundaries of an Emerging Field**

The analysis in this paper shows the dynamic process through which core and peripheral communities shape the social and symbolic boundaries of an emerging field. Figure 4 provides an overview of this process. Initially, core communities expand the definition of the field in order to
make the field appealing to more communities. Having expanded the symbolic boundary of the field, core communities define communities with more legitimacy and resources as members of the field, thereby expanding the social boundary. These new communities expand the definition of the field even further to stimulate field growth.

This expansion of the symbolic and social boundary and the increase in legitimacy and association of monetary and cultural resources is, however, a double-edged sword. The expanded symbolic boundary allows a greater number of peripheral communities seeking the field’s monetary and cultural resources to self-claim membership in the field. These claims ignite a self-reinforcing cycle. Communities’ claim to membership entices peripheral communities to further expand the symbolic boundary, making it easier for even more peripheral communities to claim membership in the field. This expansion alters the collective identity of the field, however, threatening the identity of the core communities and increasing competition for legitimacy and resources. Identity threats and increased competition push core communities to define the field more restrictively and to use this narrower definition to police the peripheral communities’ other-defining and membership claims.

Together core and peripheral communities’ quest for monetary and cultural resources shape their dynamic alterations of the social and symbolic boundary as depicted in Figure 4. Core communities’ original attempts to increase the social and symbolic boundaries of the field easily become hi-jacked by peripheral communities quest to participate in the field and access the fields’ resources. This flood of membership claims motivates core communities to restrict the symbolic boundary and use this restricted definition to police membership.

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Insert Figure 4 about here.

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DISCUSSION

Understanding the emergence of fields requires attention to the creation of their social and symbolic boundaries. While existing research has examined how core communities shape the social and symbolic boundaries separately (Weber, Heinze, and DeSoucey, 2008; Ferraro and O’Mahony, 2012), we still do not understand the interrelationship between how core and peripheral communities dynamically shape the social and symbolic boundaries of an emerging field (Lamont and Molnar, 2002; Lawrence, Suddaby and Leca, 2009; O’Mahony and Lakhani, 2011; Wry, Lounsbury and Glynn, 2011). In this paper I have taken a first step towards addressing this issue by developing a nuanced model of how core and peripheral communities interact to shape the social and symbolic boundaries of a field, and how this process is shaped by contestation over the field’s resources. Below I elaborate on how my findings contribute to several literatures including institutional work and cultural entrepreneurship, and the literature on field emergence and legitimation.

Constructing the Social and Symbolic Boundaries of an Emerging Field

There are several studies within institutional theory, which have focused explicitly on how the boundaries of fields are constructed. Scholars have shown how core communities might re-define a field’s symbolic boundary in order to gain influence and shape resource allocation (Jones et al., 2012; Lawrence, 1999; Lawrence and Suddaby, 2006). Core communities might also try to attract more legitimate communities to the field in order to increase the field’s prominence thereby expanding the social boundary (Wry, Lounsbury, and Glynn, 2011). Indeed, contracting the symbolic boundary can aid core communities in policing who participates within a field (Lawrence, 1999; Lawrence and Suddaby, 2006).

In contrast, other streams within institutional theory have focused on how field participants engage in various symbolic practices and membership claims. Granqvist, Grodal, and Woolley (2013), for example, show a lack of alignment between the technological capabilities of
nanotechnology firms and their symbolic practices. Glynn and colleagues (Glynn and Abzug, 2002; Glynn and Marquis, 2004) show how firms strategically change their names in order to claim membership in or disassociate from a field. Kim and Lyon (2014) identify how firms strategically over- and under-report their investments in environmental sustainability depending on which stakeholder they signaling to. Yet these scholars do not explicitly link these symbolic and membership claims to the construction of field boundaries.

This paper unites these different strands of work within institutional theory into an integrated model. Indeed, when companies change names (Glynn and Abzug, 2002; Glynn and Marquis, 2004) or when they claim membership in a field although their activities are a poor fit with the existing symbolic boundary (Granqvist, Grodal, and Woolley, 2013; Kim and Lyon, 2014) they are not just increasing their access to material and symbolic resources, but are contributing to the fundamental processes that drive boundary creation. This study shows that it is these actions—coupled with the responses to these actions by other participating communities—which drive boundary dynamics of emerging fields.

**Communities as a Locus of Boundary Construction**

In contrast to the existing literature on organizational fields, which has focused on individuals (Maguire, Hardy, and Lawrence, 2004) or entrepreneurial firms (Navis and Glynn, 2010), this study highlights communities as an important locus for understanding fields in general and the creation of social and symbolic boundaries more specifically. In focusing on the role of diverse communities in shaping the boundaries of emerging fields this paper takes a step in the direction advocated by O’Mahony and Lakhani (2011) and Marquis, Lounsbury and Greenwood (2011: x) that “the concept of community should be conceived as … an important underlying logic of action.” Expanding this insight I suggest that communities are an important element of fields and that understanding the varied actions taken by communities allows for a more nuanced understanding of field dynamics.
Although the literature acknowledges that fields consist of multiple communities, most research has focused on boundary construction from the perspectives of core communities only (for exceptions see Hoffman, 1999; Jones et al., 2012). For example, Gieryn (1983: 782) focuses on “ideological efforts by scientists to distinguish their work” (emphasis in the original). The focus on studying only core communities has made understanding the intricate relationship between the social and symbolic boundaries difficult. As this study shows, boundary practices are a function of the dynamic involvement of distinct communities with varying levels of identification with and stakes in the field. Indeed, without capturing the actions of both core and peripheral communities, we cannot understand the temporal evolution of boundary construction.

To the extent that the existing literature on organizational fields has theorized how different communities construct field boundaries, they have imposed a division of labor where entrepreneurial organizations strategically and symbolically claim membership in the field, and market audiences (service providers, government officials, and consumers) evaluate these membership claims (Hsu and Hannan, 2005; Hannan, Polos, and Carroll, 2007; Navis and Glynn, 2010). The current study augments this perspective by showing not only that audience members have differing views about who is a member of the field, but also that they are self-interested and proactive in creating distinctions and acting on those beliefs. These communities thus act not only as evaluators of membership claims but also as the generators of social and symbolic distinctions. Future research might therefore need to consider both who is transcending boundaries and the effects of such crossing, as well as the strategic interests audience members might have in stimulating and creating such actions in the first place. For example, to what extent are food critics not only evaluators of restaurants hybridizing classic and nouvelle cuisine (see Rao, Monin, and Druand, 2005), but also the engines of such blending processes?

This study furthers existing views on the temporal involvement of communities in field construction. While most studies on the emergence of technological fields suggest that university scientists and entrepreneurs are the communities most instrumental in shaping the boundaries of
those fields (Aldrich and Fiol, 1994; Santos and Eisenhardt, 2009), in nanotechnology most entrepreneurs and particularly university scientists were late to become involved. Most university scientists identified primarily with other fields like chemistry or materials science, and were therefore not vested enough in the field to engage in defining and policing the field’s boundary. Even during later periods, university scientists’ involvement was limited to claiming or disassociating themselves from the field.

While university scientists were not as consequential in defining and policing nanotechnology, this might not be the case for all fields. For example, in the biotechnology field, university scientists were first to define the field and identified strongly with it (Berg et al., 1975). Moreover, their definitional work attempted to minimize the breadth of the social boundary—in particular, to keep out any claims to membership from participants who engaged in activities associated with human cloning. Likewise in green-chemistry it was core scientists who identified strongly with the field and worked to police the field’s boundaries (Howard-Granville et al., 2014). This paper contributes to sorting out why the same community does not engage in similar practices across fields by pointing to a community’s degree of identification with a focal field as an important explanatory mechanism.

To understand how communities construct the boundaries of organizational fields we need to acknowledge that identification with the field varies depending on the communities’ affiliations with other fields. That is, each community is pluralistic (Glynn, 2008). This plurality creates tensions with regards to what is at stake for the involved communities, which motivates communities to dynamically change the boundaries over time. Future research might consider how various aspects of community involvement affect field emergence. For example, how do core and peripheral communities coordinate across community boundaries? What happens if several core communities have conflicting interests?

Viewing fields from the perspective of multiple communities also raises the question of the relationship between the evolving identity of the community and the evolving identity of the
field (Gioia et al., 2010). How do the identities of communities change when they become part of new fields? And how does this affect their boundary practices? For core communities in particular, is there a close link between the construction of the identity of the community and the construction of the collective identity of the field? How do peripheral communities manage their identities vis-à-vis the field? Future research might, therefore, examine how the relationship between the identity of the community and the field differ for core and peripheral communities.

**Contributions to Theories of Field Legitimation**

An important debate within the literature on field emergence is how a field becomes legitimated (Lawrence, 1999; Kennedy, 2008; Wry, Lounsbury, and Glynn, 2011). Studies of field emergence have primarily focused on the actions that lead the social and symbolic boundaries to expand and have associated this expansion with an increase in legitimation. Indeed, scholars have shown how actors mobilize interest and participation in fields (Maguire, Hardy and Lawrence, 2004; Weber, Heinze, and DeSoucey, 2008). This expansion has been theorized to increase the legitimacy of the field as growing participation increases the attention that is paid to the field (Lawrence, 1999; Kennedy, 2008).

In contrast, theories of market categories have tended to associate an increase in legitimation with the contraction of the symbolic boundary as definitions of the field become more specific and clearly defined (Hannan, Polos, and Carroll, 2007; Ruef and Patterson, 2009). These studies suggest that a contraction of the symbolic boundary is followed by a contraction in the social boundary as core participants can use the symbolic boundary to police who is viewed as a member in the field. Scholars within this tradition, thus, imply that market categories become legitimated through a more narrowly defined field. For example, Rosa et al. (1999) show how, initially, multiple conceptions of a mix between a car and a truck existed, but over time the notion of a “mini-van” came to dominate the field. This contraction of the symbolic boundary both increased the legitimacy of the field and restricted who was seen as a valid member.
This paper provides a bridge between these two approaches by showing that a field can increase legitimacy both through boundary expansion and boundary contraction. For example, in their review of the literature Lawrence and Suddaby (2005: 222) found that “most defining work focuses on the creation of ‘constitutive rules’ (Scott et al., 2000), or rules that allowed for the expansion and not the contraction of field boundaries.” In contrast, I found that definitional work can be used both to expand and contract boundaries. During the early period of field emergence expanding the social and symbolic boundary might be necessary in order to gain recognition for the field and to associate it with monetary and cultural resources. However, the increase in legitimacy is problematic in its own right, as the legitimacy of the field makes it attractive for communities with weak identification to claim membership within the field. These communities might not have been invited to participate (see Wry, Lounsbury, and Glynn 2011), but act on their own fruited. Such claims threaten to undermine the legitimacy of the field, stimulate self-disassociating and thus endanger the field with collapse.

In turn, this study creates a more nuanced account of how legitimacy is achieved in emerging fields by highlighting that legitimacy is not only bestowed upon the field through the inclusion of legitimate members (Wry, Lounsbury, and Glynn, 2011) or by aligning the field with external values (Suchman, 1995), but is also achieved by maintaining alignment and balance between the social and the symbolic boundary. Indeed, in emerging fields such legitimacy is particularly fragile, because emergence necessitates the inclusion of new members, who might perceive the social and symbolic boundary differently and whose activities might be a weak fit with the symbolic boundary. This study, therefore, opens up many new research questions about how legitimacy is created in emerging fields—in particular how legitimacy is not only achieved but also maintained. Are there different paths to the achievement of legitimacy some of which are more volatile? Which paths to legitimacy are the most successful? When? These questions are critical if we want to understand legitimacy in emerging fields.
**Boundary Conditions and Future Research**

While this study makes several important contributions, there are some boundary conditions to this work as well. Like most other studies of organizational fields, this research focuses on one field alone (e.g., Hoffman, 1999; Navis and Glynn, 2010; Zietsma and Lawrence, 2010). As the pressure to expand and contract might vary with the degree of identification among the participating communities and the legitimacy of the field, it is important for future research to conduct comparative case studies of fields that vary across these dimensions.

Another important boundary condition is that while the boundaries of the nanotechnology field were quite elastic, such elasticity might not be true for all fields. One dimension that might affect the relative fluidity of a field is the relative ease in assessing the symbolic fit of the activities of peripheral communities. We might expect, for example, more rampant membership claims in less-materialistic fields anchored around services, issues or visions. Many studies have found that the presence of material objects guide and restrict the transfer of information (Carlile, 2002; Leonardi and Barley, 2010). The materiality of the nanotechnology field was difficult to observe because the technologies were invisible to the naked eye and understanding the material structure of most products required specialized knowledge. Indeed, future research might examine the relationship between boundary practices and the relative materiality of fields.

In conclusion, how the boundaries of an organizational field are constructed is a question of central concern to institutional scholars. Yet so far we still do not know how the social and symbolic boundaries co-evolve and the role communities play in this process. This study takes an important first step towards achieving this goal by developing a nuanced model of the relationship between the creation of social and symbolic boundaries, community involvement and a field’s resources and legitimation. In doing so, this study points to communities as an important locus for understanding the dynamics of organizational fields.
<table>
<thead>
<tr>
<th>Phase</th>
<th>Technical Advances</th>
<th>Important Publications</th>
<th>Selected Firm Foundings</th>
<th>Social Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1998: The Interagency Working Group on Nanotechnology (IWGN) is formed within the US government</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1998: The Nano Science and Technology Institute (NSTI) is founded</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2000: National Nanotechnology Initiative is signed by President Clinton</td>
</tr>
<tr>
<td>contraction: 2001-2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Overview of the Data

<table>
<thead>
<tr>
<th></th>
<th>Futurists</th>
<th>Government</th>
<th>Service Providers</th>
<th>Entrepreneurs</th>
<th>University Scientists</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interviews: (77)</td>
<td>13</td>
<td>11</td>
<td>18</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>Archival data source</td>
<td>Foresight Update</td>
<td>Congressional hearings</td>
<td>Business press*</td>
<td>Press releases</td>
<td>The journal Science</td>
</tr>
<tr>
<td>Articles analyzed quantitatively: (9,011)**</td>
<td>926</td>
<td>925</td>
<td>494</td>
<td>4,157</td>
<td>509</td>
</tr>
<tr>
<td>Articles analyzed qualitatively: 938***</td>
<td>204</td>
<td>142</td>
<td>189</td>
<td>170</td>
<td>233</td>
</tr>
<tr>
<td>Size Members</td>
<td>Very small</td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
<td>Large</td>
</tr>
<tr>
<td></td>
<td>Participants at activities organized by the Foresight Institute.</td>
<td>Members of government agencies and work groups.</td>
<td>Lawyers, consultants, venture capitalists, conference organizers, and journalists.</td>
<td>Employees at companies.</td>
<td>Researchers at universities and government labs.</td>
</tr>
</tbody>
</table>

**Core communities**

<table>
<thead>
<tr>
<th>Identification with the nanotechnology field</th>
<th>Strongest</th>
<th>Strong</th>
<th>Mixed</th>
<th>Weak</th>
<th>Weakest</th>
</tr>
</thead>
<tbody>
<tr>
<td>The futurist community was founded in order to stimulate and manage the nanotechnology field.</td>
<td>Government officials championed the creation of the NNI. Their stake in nanotechnology shaped their self-perceptions.</td>
<td>Most service providers had a fleeting interest in nanotechnology. Few were dedicated to the field.</td>
<td>Many entrepreneurial companies either already identified with another field. Few identified primarily with nanotechnology.</td>
<td>Most scientists perceived their scientific discipline as the main locus for identification.</td>
<td></td>
</tr>
</tbody>
</table>

**Example**

```
We were focused on developing nanotechnology... nanotechnology was the reason the Foresight Institute was founded".
```
```
"[T]he NNI became one of our core initiatives...for some this became the defining project of their tenure."
```
```
"We founded NanoTrade to serve the growing interest in nanotech." Vs: "We jumped in because that was what people wanted to hear."
```
```
"I see us as an instrumentation company...We go to nanotech things sometimes: "We do biotech, nanotech, lab-on-a-chip."
```
```
"I only refer to my work as nanotech in grant applications".
```
```
"[N]anotech is not really what we do."
```

Note: Totals listed in parenthesis.


**The archival data listed above were supplemented with additional important documents that were pivotal in the development of nanotechnology.

***Many of the articles were only one or two paragraphs.
Table 3: The Use of the Boundary Practices across Communities

<table>
<thead>
<tr>
<th>Communities</th>
<th>Futurists</th>
<th>Government</th>
<th>Service providers</th>
<th>Entrepreneurs</th>
<th>University scientists</th>
<th>Effect at the interaction level</th>
<th>Strength of the practice across the communities</th>
<th>Effect on the field boundary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification with nanotechnology</td>
<td>Core communities</td>
<td>Peripheral communities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symbolic boundary practices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enlarging the definition</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>Expansion</td>
<td>Medium</td>
<td>Expansion</td>
</tr>
<tr>
<td>Restricting the definition</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
<td>Contraction</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>Social boundary practices</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Expansion</td>
<td>Medium</td>
<td>Expansion</td>
</tr>
<tr>
<td>Other-defining</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
<td>Expansion</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Self-claiming</td>
<td></td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Expansion</td>
<td>Strong</td>
<td></td>
</tr>
<tr>
<td>Other-policing</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Contraction</td>
<td>Weak</td>
<td></td>
</tr>
<tr>
<td>Self-disassociating</td>
<td></td>
<td></td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>Contraction</td>
<td>Weak</td>
<td></td>
</tr>
</tbody>
</table>
### Table 4: Boundary Practices during the Emergence of the Nanotechnology Field

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legitimacy</strong></td>
<td>Low legitimacy</td>
<td>Legitimation</td>
</tr>
<tr>
<td></td>
<td>Futurist community was perceived fringe.</td>
<td>Government involvement increased the legitimacy of the field.</td>
</tr>
<tr>
<td><strong>Government funding</strong></td>
<td>~ $110 mill. pr. year*</td>
<td>~ $230 mill. pr. year</td>
</tr>
<tr>
<td>VC funding</td>
<td>&lt; $92 mill. pr. year*</td>
<td>~ $660 mill. pr. year</td>
</tr>
</tbody>
</table>

**Boundary practices**

<table>
<thead>
<tr>
<th>Expansive boundary practices</th>
<th>Symbolic Enlarging</th>
<th>Contracting boundary practices</th>
<th>Symbolic Restricting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>Other-defining</td>
<td></td>
<td>Self-disassociating</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Expansive boundary practices**

**Social**

- **Other-defining**
  - Futurists included peripheral communities in the field.
  - The government engaged in other-defining to increase the social boundary.
  - Service providers engaged in other-defining to include more members in the field.

**Self-claiming**

- Entrepreneurs and scientists engaged in self-claiming to gain access to the field’s resources.
  - The legitimacy of the field stimulated self-claiming by entrepreneurs and scientists.

**Contracting boundary practices**

**Social**

- **Other-policing**
  - Futurists and government officials tried to police membership claims.
  - Prominent entrepreneurs and scientists began self-disassociating due to perceptions that the legitimacy of the field was threatened.

*Data only available for 1997, because money flowing to nanotechnology was not tracked prior to this time.*
A futurist, John Malcolm, explained: “[T]his involved speaking to various people, various groups. The Foresight Institute stimulated that interest and got people together and talking and becoming aware of some of the things that were feasible.”

One government official, Tim Kleinbaum, explained how the definition was enlarged: “So, I should step back and say that obviously when you are developing these you are communicating with multiple audiences. You need to build this broad coalition of individuals, companies, agencies, the Congress, the media, politicians, speechwriters, the Office of Management and Budget, etc., etc. …You need to develop arguments and messages and documents that are responsive to these different communities.”

In 2003, futurist Eric Drexler called for a restriction of the nanotechnology definition: “Much of the work being done today that carries the name ‘nanotechnology’ is not nanotechnology in the original meaning of the word. Nanotechnology, in its traditional sense, means building things from the bottom up, with atomic precision…. Unfortunately, conflicting definitions of nanotechnology and blurry distinctions between significantly different fields have complicated the effort to understand the differences and develop sensible, effective policy……”

In an article published in 2004, Christine Peterson described: “Researchers from many fields began to re-label and adapt their work as ‘nanotechnology,’ partly to make clear the interconnections, and partly to jump on what was coming to be a funding bandwagon.”

Gabriella Perrelli, a service provider, stated: “As I’ve watched it [nanotechnology], I’ve seen two things. You take what you’ve got and you put lipstick on it or you make it wear a hat and suddenly it is nanotechnology. In terms of funding—the National Nanotechnology Initiative—what happens in funding cycles is that people see proposals as whatever it is that they happen to be doing. If you’re offering money and you’re telling me that you want ‘blue stuff’ then I’m going to make these guys wrap it up with a blue package and put a blue ribbon on it and say, ‘I’m doing blue stuff.’ So that happened in nanotechnology as well. So they said, ‘I take what I’ve got and put a hat on it, and I become nano’.”

One government official explained: “And in general when talking with policymakers…they really need to understand that, first of all, the best and the brightest researchers are interested in working in this area…. It’s not easy to sell these people a used car so most politicians I work with are pretty alert and they’ve heard everything. People have tried to sell them everything. So they’ve got to know that there’s substance there, there’s real quality, and the easiest way to convince them of that is to show them that some of the best scientists and engineering researchers are actually working on the area ‘cause they think it’s important’.

“My take is that people are always trying to stretch the definition of nanotechnology in various ways to showcase a series of successful products. I think people stretch the definition of nanotechnology to include my company because we have products and all that other stuff, and they’re like, “Alright, is somebody out there? Oh, there’s Waxmini, you guys are nanotech, aren’t you?” Well, you tell me!”

Jeff Feinberg, CEO of a materials company, said: “I would say that [being labeled nanotechnology] may have a negative effect on firms from a fundraising perspective. It is a struggle for a company that gets labeled as nanotechnology, and frankly it’s very hard for ANS [Applied Nano Solutions] not to be labeled as nanotechnology because nano is in our name. That name was chosen in 1999—long before it became fashionable to even talk of nanotechnology as an industry. So what that means is that regardless of where you are in the product-development cycle you suffer. And that’s something that we’ve had to overcome by distancing ourselves from nanotechnology.”

A conference organizer, Michael Smith, for example, explained that in deciding which companies would get to present at their nanotechnology conference they would go through a vetting process with the board to identify which companies complied with the use of the nanotechnology label: ‘When you deal with the early stage companies, the commissions that come in, we look at them, and there are very few what I would call ‘pure play’ nanotech companies. So what you have is a company that like any normal company has an industrial market it’s trying to service and just happens to have some IT that has something at the micro and nano scales. So we look at those and the venture capital reviewers would look at it and say, ‘Well, this isn’t a nano company because it’s selling its product to the aerospace industry.’”

---

Table 5: Examples of the Boundary Practices

<table>
<thead>
<tr>
<th>Enlarging the definition</th>
<th>A futurist, John Malcolm, explained: “[T]his involved speaking to various people, various groups. The Foresight Institute stimulated that interest and got people together and talking and becoming aware of some of the things that were feasible.”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restricting the definition</td>
<td>In 2003, futurist Eric Drexler called for a restriction of the nanotechnology definition: “Much of the work being done today that carries the name ‘nanotechnology’ is not nanotechnology in the original meaning of the word. Nanotechnology, in its traditional sense, means building things from the bottom up, with atomic precision…. Unfortunately, conflicting definitions of nanotechnology and blurry distinctions between significantly different fields have complicated the effort to understand the differences and develop sensible, effective policy……”</td>
</tr>
<tr>
<td>Self-claiming</td>
<td>In an article published in 2004, Christine Peterson described: “Researchers from many fields began to re-label and adapt their work as ‘nanotechnology,’ partly to make clear the interconnections, and partly to jump on what was coming to be a funding bandwagon.”</td>
</tr>
</tbody>
</table>
| Other-defining | One government official explained: “And in general when talking with policymakers…they really need to understand that, first of all, the best and the brightest researchers are interested in working in this area…. It’s not easy to sell these people a used car so most politicians I work with are pretty alert and they’ve heard everything. People have tried to sell them everything. So they’ve got to know that there’s substance there, there’s real quality, and the easiest way to convince them of that is to show them that some of the best scientists and engineering researchers are actually working on the area ‘cause they think it’s important’.

“My take is that people are always trying to stretch the definition of nanotechnology in various ways to showcase a series of successful products. I think people stretch the definition of nanotechnology to include my company because we have products and all that other stuff, and they’re like, “Alright, is somebody out there? Oh, there’s Waxmini, you guys are nanotech, aren’t you?” Well, you tell me!” |
| Self-disassociating | Jeff Feinberg, CEO of a materials company, said: “I would say that [being labeled nanotechnology] may have a negative effect on firms from a fundraising perspective. It is a struggle for a company that gets labeled as nanotechnology, and frankly it’s very hard for ANS [Applied Nano Solutions] not to be labeled as nanotechnology because nano is in our name. That name was chosen in 1999—long before it became fashionable to even talk of nanotechnology as an industry. So what that means is that regardless of where you are in the product-development cycle you suffer. And that’s something that we’ve had to overcome by distancing ourselves from nanotechnology.” |
| Other-policing | A conference organizer, Michael Smith, for example, explained that in deciding which companies would get to present at their nanotechnology conference they would go through a vetting process with the board to identify which companies complied with the use of the nanotechnology label: ‘When you deal with the early stage companies, the commissions that come in, we look at them, and there are very few what I would call ‘pure play’ nanotech companies. So what you have is a company that like any normal company has an industrial market it’s trying to service and just happens to have some IT that has something at the micro and nano scales. So we look at those and the venture capital reviewers would look at it and say, ‘Well, this isn’t a nano company because it’s selling its product to the aerospace industry.’” |
Figure 1: Overview of the Coding Structure

1st Stage
Creating social and symbolic boundaries

2nd Stage
Identifying expansion and contraction

3rd Stage
Identifying six boundary practices

4th Stage
Core and peripheral communities

5th Stage
Identifying boundary co-evolution

We tried to expand the definition of nano to appeal to different stakeholders.
During the political process, we had to come up with a definition that would work for all parties.

We had to try to limit the definition of nanotechnology so that not everyone could claim that they were nano.
We make a conscious effort to come up with a more specific definition of nanotechnology.

I now refer to my work as nanotechnology.
Our company has changed its name, so people now identify us as nanotechnology.

When people ask, I tell them we are not nano.
I have been asked to join a university task force on nanotechnology, but I am not sure I want to be involved with this field.

I have seen my name on lists of nanotechnology researchers, even though I do not consider my work to be nanotechnology.
The government wants us to be nano because not many other firms are as successful as we are.

I call people out when they claim to be nano and they are not.
I throw our grant applications that are not within the nano...
Figure 2: Expansion of the Symbolic Boundary of Nanotechnology

Phase 1: Boundary creation: 1980s – 1996
1995, Feb. 21, *Washington Post*: “the science of creating matter from its basic atoms with the aid of tiny, molecule-size machines”

Phase 2: Boundary expansion: 1997-2000
1997, May 7, *Boston Globe*: “the creation of molecular-sized machines that replicate and organize themselves into bigger and bigger units, eventually becoming useful things”

Phase 3: Attempted boundary contraction: 2001-2005
2001, Oct. 10 *USA Today*: “atom-sized materials and components”
2002, Nov. 10 *Boston Globe*: “the emerging field of molecular-level engineering”
2004, May. 17 *Washington Post*: “deals with molecules just billionths of a meter in size”

Note: The y-axis in Figure 2 represents individual raters’ assessments of the breadth of each nanotechnology definition. For a detailed description of how each definition was coded, see Appendix 3.

Below Figure 2 I provide examples of definitions from the top 50 US newspapers for each of the three phases.
Figure 3: Expansion of the Social Boundary of Nanotechnology

Note: The y-axis in Figure 3 represents the percentage of articles about nano-science that also mention nanotechnology. Figure 3 thus illustrates that timing and intensity with which the five different communities began to participate in the nanotechnology field.
The relative strength of the boundary practices influences the overall contraction or expansion of the social and symbolic boundaries of the field.
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