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ORGANIZATIONAL DIVERSITY AND INDUSTRY EVOLUTION: THE ENTRY OF MODERN BIOTECHNOLOGY FIRMS IN FINLAND 1973-2006

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Abstract

Cooperative and competitive interrelationships are central to organization theory. Organizational ecology, and density-dependence theory in particular, investigates how large-scale institutional and competitive processes affect the entry of new organizations, and thus large-scale industry evolution. To date, existing ecological research has focused on populations of organizations that are relatively homogeneous with respect to their organizational form – often defined through salient product markets. However, some organizational forms are complex, thus resulting in heterogeneous populations, as exemplified by the biotechnology industry. Biotechnology firms hold a common technology base but operate at diverse product markets with different strategies and organizational forms. The present study investigates what implications such heterogeneity has on the mutualistic and competitive relationships within a population, and how this affects the predictions of density-dependent entry.

The identity approach to organizational forms is used as a basis for conceptualizing complex forms as systems of hierarchically nested sub-forms. Hypotheses are derived regarding density-dependent entry in heterogeneous populations characterized by complex organizational forms. The hypotheses are tested with comprehensive data on the modern biotechnology industry in Finland in 1973-2006, including its twelve sub-forms and four intermediate clusters of sub-forms. All of the hypotheses receive full or partial support, depending on the system structure applied.

A key finding of the study is that the systemic structure underlying the complex form of Finnish modern biotechnology has clear implications to the density-dependent processes of legitimation and competition. In other words, the sub-populations are not isolated from effects stemming from other sub-populations. In addition, it is found that the processes of legitimation operate on a broader scale than the processes of ecological competition.

The present study contributes to organization theory by shedding additional light on (i) the mechanisms creating organizational diversity, (ii) how such diversity is structured, and (iii) what implications such diversity has on the large-scale mutualistic and competitive interdependencies between organizations. In particular, the study brings additional understanding on the levels at which mutualistic and competitive forces operate. For the domain of organizational ecology the study shows that the distinction between simple and complex organizational forms is meaningful, and demonstrates the analytical power of the identity and systems approaches. Density dependence theory is extended by proposing how legitimation and competition operate in settings with complex organizational forms.

A key implication to policy-making is that the excessive focusing on a single sub-sector may have negative consequences on organizational entry. Government intervention and different forms of collective industrial action may also work to deliberately boost legitimizing effects and minimize unnecessary competitive constraints. Finally, management practice is advised to follow legitimized forms, to avoid low-legitimation-high-competition traps, and to promote the general legitimation of the field.

Keywords:
Organizational ecology; density-dependence; complex organizational forms; heterogeneous populations

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Tiivistelmä

Organisaatioiden väliset yhteisölliset ja kilpailulliset vuorovaikutussuhteet ovat keskeisiä alueita organisaatiotutkimuksessa. Organisaatioekologia ja sen alla erityisesti tiheysriippuvuusteoria tarkastelevat, miten institutionaaliset ja kilpailulliset mekanismit vaikuttavat populaatiotasolla uusien yritysten ilmestymiseen tietylle toimialalle. Tällä on puolestaan vaikutuksia toimialan evoluutioon ja kasvuun. Tähän mennessä ekologiatutkimus on suurelta osin keskittynyt organisaatiopopulaatioihin, joiden taustalla oleva organisaatiomuoto on varsin homogeeninen. Populaatioiden määrittämisessä on usein käytetty helposti havaittavia tuotemarkkinoita (esim. autonvalmistajat). On kuitenkin olemassa ns. kompleksisia organisaatiomuotoja, joita vastaavat populaatiot ovat selvästi heterogeenisiä. Bioteknologiatoimiala on hyvä esimerkki. Bioteknologiayritysten taustalla on yhteinen teknologiapohja, mutta yritykset toimivat useilla tuotemarkkinoilla ja omaksuvat erilaisia organisaatiomuotoja ja strategioita. Käsillä oleva tutkimus selvittää, mitä vaikutuksia tällaisella monimuotoisuudella on yhteisöllisiin ja kilpailullisiin riippuvuussuhteisiin ja sitä kautta tiheysriippuvuusteorian mukaisiin ennusteisiin uusien organisaatioiden ilmestymistä koskien.

Tutkimuksen analyyttinen viitekehys nojautuu organisaatiomuotojen identiteettiteoriaan. Kompleksisia organisaatiomuotoja lähestytään systeemisten rakenteiden kautta. Oletuksena on, että kompleksinen organisaatiomuoto koostuu hierarkkisesti järjestäytyneistä alamuodoista, joilla on päämuotoa yksinkertaisempi kollektiivinen identiteetti. Tiheysriippuvuusteoriaa sovelletaan yhteensopivaksi tällaisiin rakenteisiin, ja tämän pohjalta esitetään hypoteeseja liittyen uusien organisaatioiden ilmestymiseen heterogeenisissä populaatioissa. Hypoteeseja testataan aineistolla, joka kattaa koko modernin biotekniikkatoimialan Suomessa 1973-2006. Aineisto käsittää toimialan sisällä olevat 12 alapopulaatiota sekä neljä alapopulaatioiden klusteria. Kaikki esitetyt hypoteesit saavat aineiston pohjalta osittaisen tai täyden tuen.

Tutkimuksen ensimmäinen päähavainto on, että kompleksisen organisaatiomuodon systeemisellä rakenteella on selvä vaikutus legitimaatio- ja kilpailuprosesseihin, ja näin ollen myös uusien yritysten ilmestymiseen. Muilla pääpopulaation alla olevilla alapopulaatioilla on vaikutuksia yksittäisen alapopulaation evoluutioon. Lisäksi havaitaan, että legitimoivat prosessit vaikuttavat laajemmalla tasolla kuin kilpailulliset.

Organisaatiotutkimusta edistetään valaisemalla (i) millaiset mekanismit luovat organisaatioiden monimuotoisuutta, (ii) millaisia rakenteita tällaisen monimuotoisuuden taustalla on, ja (iii) mitä vaikutuksia tällä monimuotoisuudella on organisaatiopopulaatioiden evoluutioon. Tutkimus tuottaa lisätietoa erityisesti yhteisöllisten ja kilpailullisten vaikutusten ulottuvuudesta organisaatiokentissä. Organisaatioekologiaan liittyen osoitetaan, että yksinkertaisten ja kompleksisten organisaatiomuotojen erotteleminen on analyyttisessä mielessä järkevää. Tiheysriippuvuusteoriaa edistetään osoittamalla, miten organisaatioiden monimuotoisuus vaikuttaa legitimaatio- ja kilpailuprosesseihin.

Tutkimuksella on implikaatioita myös valtiolliseen päätöksentekoon. Tulosten valossa on mahdollista, että liiallisella panosten kohdentamisella bioteknologia- ja vastaavien toimialojen tiettyyn yksittäiseen alasektoriin voi olla negatiivisia vaikutuksia uusien yritysten syntymiseen ja siten toimialan kehittymiseen. Valtiollinen interventio sekä kollektiivinen toiminta toimialan sisällä voivat kuitenkin edistää legitimoivia vaikutuksia ja minimoida tarpeettomia kilpailullisia rajoitteita. Lisäksi yritysjohdon suuntaan voidaan todeta, että yritysten kannattaa seurata legitimoituja organisaatiomuotoja, välttää alhaisen legitimaation ja korkean kilpailun asetelmia, sekä edistää toimialansa yleistä legitimointia.

Asiasanat:
Organisaatioekologia, tiheysriippuvuus, kompleksiset organisaatiomuodot, heterogeeniset populaatiot

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Juha Mattsson

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1 Introduction

Both cooperative and competitive relationships between organizations are central subjects in organization theory. The focus is often on dyadic cooperative or competitive relationships between a small number of individual organizations. However, with the advent of the open-systems perspective in organization theory (Scott, 2003: ch. 4), attention has increasingly turned to the relationship between organizations and their broader environment (Aldrich, 1979). A number of fields have their attention on the mutualistic and competitive forces that are generated by, and affect, organizations as members in the overall organizational environment – populated by large quantities of organizations not in direct relationships to each other. Institutional theory (DiMaggio *et al.*, 1983; Meyer *et al.*, 1977) focuses on how organizations and organizational forms gain taken-for-granted status by following institutional behavior and patterns compatible with other organizations and external social units. Resource dependence theory (Pfeffer *et al.*, 1978) regards how interorganizational relationships control access to vital resources and thus constrain organizational action. Finally, organizational ecology (Hannan *et al.*, 1977, 1989) investigates how mutualistic and competitive interdependencies together affect organizational viability and survival, resulting in dynamic distributions of organizational forms adapted to the contemporaneous environmental configurations surrounding them.

According to general evolutionary principles, the entry of new organizations is a key process that affects diversity, growth, and change in the overall organizational landscape (Aldrich, 1999: 1). Within the ecological approach, extensive effort has been put to develop and test the density dependence theory (Hannan, 1986; Hannan *et al.*, 1992) which holds that the entry of new organizations is significantly affected by mutualistic and competitive forces at the level of organizational populations. According to the theory, cognitive legitimation of the underlying organizational form generates mutualistic effects, while dependence of common resources from the environment generates competitive pressures (Hannan, 1986). By influencing entry, these forces have a major impact on organizational evolution and thus large-scale social change (cf. Hannan *et al.*, 1989). The predictions of density-dependence theory are supported by an extensive body of empirical studies that cover a broad array of different industrial settings (cf. Carroll *et al.*, 2000a: 218). The theory has been tested and validated in many common industrial sectors such as automobile manufacturing (Hannan *et al.*, 1995c), banks (Lomi, 1995a, 2000), hotels (Baum, 1995; Ingram *et al.*, 1996; Ranger-Moore *et al.*, 1991), newspaper publishing (Carroll *et al.*, 1989b; Dobrev, 2001), and day care centers (Baum *et al.*, 1992b; Baum *et al.*, 1994a) to mention a few.

Density dependence – and the ecological approach in general – rests on the fundamental assumption that the members of an organizational population are homogeneous with respect to their core properties, including the product market served, stated goals, forms of authority, and core technology (Hannan *et al.*, 1984). Such homogeneity follows from the underlying conceptual idea that all members of a population share a common organizational form (Hannan *et al.*, 1977, 1984). While ambiguity and disagreement exist for the theoretical underpinnings of the concept of organizational form (cf. McKendrick *et al.*, 2003; Polos *et al.*, 2002; Romanelli, 1991), it is generally agreed that forms are socially constructed and are used in identifying organizations that are ecologically similar (Aldrich, 1999: 37, 47). Such similarity is also related to the concept of niche. Niches are sets of environmental resources that "consist of the social, economic, and political conditions that can sustain the functioning of organizations that embody a particular form" (Hannan *et al.*, 1995a: 34). The organizations that share a common form (e.g. the members of a population) are dependent on a common material and social environment and thus are affected homogeneously by forces stemming from the environment (Hannan *et al.*, 1989: 45).

Unfortunately, a majority of the extensive body of empirical work in organizational ecology has not explicitly applied the concept of organizational form in defining empirical populations (cf. McKendrick *et al.*, 2001). This is a possible consequence of the theoretical ambiguity regarding the concept of form. The above, as well as the original idea of intra-population homogeneity have implicitly lead to a general focus on relatively homogeneous populations with simple forms, often defined grossly through salient product markets and pre-existing industrial categories (cf. Hsu *et al.*, 2005).

However, populations are often far from homogeneous (cf. Cattani *et al.*, 2003). Indeed, for some populations, researchers have found mixed results from the baseline density dependence model (e.g. Boone *et al.*, 2000; McKendrick *et al.*, 2003) which implicitly assumes that the members of a population are relatively homogeneous. Thus, ecological research has increasingly turned attention into the effects of microstructures and internal boundaries within individual populations (e.g. Boone *et al.*, 2002; Cattani *et al.*, 2003; Dobrev *et al.*, 2001; Greve, 2002a; Hannan *et al.*, 1995c). For example, many industries face diverse environments with geographically unevenly distributed resource abundances such as consumer demand (Aldrich, 1979; Chandler, 1990; Hannan *et al.*, 1995c; Krugman, 1995). This causes spatial heterogeneity within organizational populations and such heterogeneity has been found to affect the predictions of density dependent entry (Greve, 2002a; Lomi, 1995b, 2000; Wezel, 2005).

An additional type of heterogeneity is related to organizational forms. The identity approach to organizational forms posits that an organizational form is an externally enforced, rule-like collective identity[1] (Polos *et al.*, 2002). Such identities are defined by sets of social codes or rules, conformity to which is enforced by external audiences that have the power to affect organizational success and failure (Hsu *et al.*, 2005). Put differently, audiences develop a common understanding (i.e. identity) of a specific organizational type (i.e. form) in terms of a shared set of social codes. Thus the externally enforced identity essentially defines a form. The audiences screen and

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[1] Note that here the concept of identity refers to an *external* identity that some external audience associates to an organizational form. This conception of identity differs in a fundamental way from the one used within the field of organizational behavior where identity is formed internally by a collective self-conception process among the members of an organization. Examples of such external audiences include customer base, the general public, supplier organizations, government authorities, and so forth.

validate organizations as members of the form in terms of conformity to the codes. The failure of an organization to conform to an externally enforced code results in devaluations by the audiences. This again decreases the viability and survival chances of such organizations[2].

Some organizational forms may have several disparate audiences that collectively associate a rather heterogeneous set of organizations (and thus expected organizational properties and behavior) to the form's collective identity and label. Such organizational forms can be characterized as complex (Hsu et al., 2005; Zuckerman et al., 2003) and are different from simple organizational forms which have more unified collective identities and fewer associated audiences. The complexity of a form is reflected as a special type of (non-geographical) heterogeneity in empirical organizational populations (cf. McKendrick *et al.*, 2003).

The biotechnology industry is a prime example of a heterogeneous population characterized by a complex organizational form. Biotechnology holds a common technology/knowledge base (Walker et al., 1997), but is populated by a diverse set of organizations operating in various product markets with different strategies and business models (Baum et al., 2000; Luukkonen, 2005). Examples of the distinct product markets within biotechnology include pharmaceuticals, diagnostics, industrial chemicals, and waste management, to name a few (Baum et al., 2000; Liebeskind et al., 1996; Oliver, 2001; Powell et al., 1996; Walker et al., 1997). Thus a diverse set of organizations is associated to the overarching complex organizational form of biotechnology. However, relatively clear sub-identities and sub-forms can be identified within the main form, as exemplified by the finite number of underlying but distinctive product markets.

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[2] A simple example of a code would be the credit rating of a company. Having problems in debt payments or otherwise deviating from appropriate financial standards is shown by a lower credit rating. Banks and other financial institutions (as audiences) screen companies in terms of their credit rating. Having a low rating makes obtaining debt finance relatively difficult. This may again affect the viability and even survival chances of the company.

Very little attention (Dobrev *et al.*, 2006; Ruef, 2000) has been devoted to theoretical and empirical work to examine the density-dependent processes of legitimation and competition in heterogeneous populations characterized by complex organizational forms. However, extant ecological research has studied intra-population heterogeneity from several other angles. In addition to the spatial heterogeneity mentioned above, organizational size distributions (Barnett, 1997; Barnett *et al.*, 1990; Barnett *et al.*, 2004a), dynamics of niche width and resource partitioning (Boone *et al.*, 2000; Carroll, 1985; Dobrev *et al.*, 2001), niche overlap (Baum *et al.*, 1994a, 1994b), as well as temporal heterogeneity (Hannan, 1997; Wezel, 2005) have been found to have implications on how ecological processes of mutualism and competition operate in organizational populations.

An intriguing question then becomes: How do mutualistic and competitive interrelationships affect organizational evolution in such heterogeneous populations characterized by complex organizational forms? In particular, are the effects of mutualism and competition uniform across the whole population, or do they cluster within specific parts of the population? If so, how are such forces affecting the overall evolution of the population? In the context of geographical heterogeneity, some evidence exists that mutualistic effects operate on a broader scale than competitive effects (Hannan *et al.*, 1995c). Does a similar logic apply also in the case of heterogeneity caused by form complexity? In other words, using the biotechnology industry again as an example, do biopharmaceutical firms exert an equal competitive pressure to e.g. agrobiotechnology firms as they do to other biopharmaceutical firms? How about the effects of mutualism and legitimation?

The present study takes the density dependence approach as the platform for scrutinizing the above questions in relation to organizational entry. Thus the formal research question can be stated as follows:

How do density dependent processes of legitimation and competition affect organizational entry in heterogeneous populations characterized by complex organizational forms?

The following sub-question is of particular interest:

Which mechanisms cause legitimation and competition and how are these effects distributed within such populations?

To proceed with the analysis, one needs to choose the analytical approach to capture the heterogeneity caused by form complexity. If a complex form, like biotechnology, encompasses a relatively wide array of different kinds of organizations, how can such populations be meaningfully approached for systematic analysis? Classic work in both human ecology (Hawley, 1950) and organizational ecology (Hannan *et al.*, 1977) have stressed the systemic nature of social structures, and the isomorphism (Hawley, 1968) between the diversity of organizational forms and the diversity of environments. Although organizations are often seen as "the fundamental building blocks of modern societies and the basic vehicles through which collective action occurs" (Aldrich, 1999: 5), organizational phenomena and evolutionary processes can be studied at various levels of analysis, ranging from individuals through intraorganizational units, organizations, and organizational populations to organizational communities (Amburgey *et al.*, 1996; Hannan *et al.*, 1977). These levels form social systems that have hierarchical structures with nested levels and related, interdependent sub-units.

Prior research has successfully applied a systems approach e.g. to capture the spatial heterogeneity of populations (Carroll *et al.*, 2000a: 253-255; Cattani *et al.*, 2003; Greve, 2002a; Hannan *et al.*, 1992: 98-100; Hannan *et al.*, 1995c; Lomi, 1995a). The idea is that a geographically bounded (e.g. national) population has spatially clustered sub-populations (e.g. cities or regions). The relationships between the individual sub-populations and effects across the different levels of such multilevel systems have implications on how the processes of density-dependent legitimation and competition operate. In an other vein, research on community ecology focuses on settings where a number of populations occupy non-overlapping niches but hold symbiotic interdependencies on each other (Aldrich, 1999: ch. 11; Hawley, 1950: 40-41). A typical symbiotic setting is a case where a population of producers holds vital and supporting dependence relationships to both the population(s) of supplier organizations as well as to the population(s) of customer organizations (Hannan *et al.*, 1995a: 30). Such structures are also systemic (cf. Barnett, 1990).

A similar systems approach enables one to conceptualize complex organizational forms (and heterogeneous populations thereof) as systems of hierarchically nested, simpler sub-forms (and sub-populations) (cf. Carroll *et al.*, 2000a: 76-78). Recent developments in the identity approach to organizational forms have pointed out the systemic properties of forms (cf. McKendrick *et al.*, 2001). Organizational identities are often hierarchically nested, comprising of sub-identities related to each other (cf. Carroll *et al.*, 2000a: 69). Thus, organizational forms – as collective identities – may also have nested sub-forms with related identities (Carroll *et al.*, 2000a: 74; Ruef, 2000). Based on the above, the core idea of the systems approach is that complex organizational forms have systemic internal structures that comprise of hierarchically nested, simpler sub-forms with related identities. Such systemic structures are mirrored to related empirical populations. Sub-populations are hierarchically nested under a heterogeneous main population and they hold systemic relationships to one another and the main population. Interestingly, in a related vein, students of organizational taxonomy have even proposed that organizational forms could be classified into universal family trees based on an organizational genetics approach that traces organizational routines and competencies ("comps") in a way that resembles the role of genes in determining biological classifications of species (McKelvey, 1982; McKelvey *et al.*, 1983).

The present study adopts the above identity-based systems approach to investigate density-dependence in heterogeneous populations characterized by complex organizational forms. Hypotheses are derived regarding how the density-dependent processes of legitimation and competition affect entry in such settings. To test the hypotheses, the modern biotechnology industry in Finland between 1973 and 2006 is chosen as the empirical context. In the Finnish case, the overarching biotechnology form holds a salient identity among several external audiences – the general public, press, government authorities, academia, investors, biotechnology experts, and so on. Nonetheless, the main form is complex and draws together a diverse set of organizations with the technological base as the common denominator. In particular, several distinct product-markets and/or application areas can be identified, some of which are completely non-related (bioenergy vis-à-vis biopharmaceuticals, for example). This contrasts strongly with the empirical populations featured in a majority of the existing ecological studies.

The systems approach works well in capturing the complexity of the organizational form underlying the Finnish biotechnology industry. Altogether twelve distinct sub-forms can be identified whose identities are at the same time conspicuously distinct as well as related to each other and the main form. A majority of the sub-forms center on the different product markets and (thus) hold identities that are clearly simpler in comparison to the main form. Two alternative but related systemic structures can be applied to depict the configuration of the sub-forms. The most straightforward way is to see the individual sub-forms nested directly under the main form. An alternative way is to add an intermediate "cluster" level where a number of related sub-forms are grouped together as kind of clusters. Examples of such cluster include healthcare biotechnology (including biopharmaceuticals, biomaterials, diagnostics, bioinformatics, and R&D service) and industrial biotechnology (including enzymes, bioproduction, bioenergy, and environment related biotechnology). The system of forms is accurately mirrored into the empirical population of firms. The Finnish biotechnology industry has a systemic structure with 12 separate sub-populations that are nested hierarchically under the heterogeneous main population.

A wide array of sources is triangulated to construct a comprehensive dataset of the Finnish biotechnology industry and its constituent sub-populations. The reliability of the data is tested by using a special card-sorting technique in interviews with six Finnish biotechnology industry experts. The database covers the entries of altogether 401 Finnish biotechnology firms between 1973 and 2006. The maximum density of 269 firms can be observed for the year 2004. Density is measured on three levels: sub-populations, clusters of sub-populations, and the main population. To test the hypotheses, negative binomial regression models are specified for organizational entry rates on the main population and sub-population level. A majority of the hypotheses receive full support, while a few are only partially supported, depending on the system structure applied.

The key findings of the study can be summarized as follows. First, it is found that the systemic structure of the underlying complex form has clear implications to the operation of the processes of density-dependent legitimation and competition. When the individual sub-populations are observed in isolation from the rest of the system, the density-dependent effects are weak and work in ambiguous directions. When the whole main population is observed as a single, uniform entity, the baseline density-dependence model seems to work adequately. However, the systems approach is clearly more powerful in capturing the effects stemming from the underlying diversity, compared to an approach based on a single uniform organizational form. The different units and levels have clear communal interdependencies, and exert mutualistic and competitive forces on one another.

Second, it is found that, as predicted, legitimation tends to operate on a broader scale than competition. Within the simple systemic structure with the sub-populations nested directly under the main population, virtually all ecological competition is contained to the sub-population level. However, the main population, including also effects from all other sub-forms of biotechnology, has a much stronger legitimizing effect on sub-population entry than the individual sub-populations themselves. Interestingly, as the intermediate cluster level is added to the hierarchy, the effects of the main population disappear completely. Competition is again wholly contained to the sub-population level, but now the effects of legitimation can be detected only at the cluster level.

The present study contributes to organization theory by shedding additional light on (i) the mechanisms creating organizational diversity, (ii) how such diversity is structured, and (iii) what implications such diversity has on the large-scale mutualistic and competitive interdependencies between organizations. In particular, the study brings additional understanding on the levels at which mutualistic and competitive forces operate. For the domain of organizational ecology, the present study contributes by carrying forward the original mission to understand "why are there so many kinds of organizations" (Hannan *et al.*, 1977). The study shows that the distinction between simple and complex organizational forms is meaningful, and demonstrates the analytical power of the systems approach to comprehend the internal structures of complex forms. The study also brings additional confirmation to the viability of the identity approach in conceptualizing organizational forms, as well as to the operationalization of forms to empirical settings. Density dependence theory is extended by proposing how legitimation and competition operate in settings with complex organizational forms and underlying multilevel systems of forms (cf. Carroll *et al.*, 2000a: 76-78). The findings also bring additional evidence to back up the idea that effects of legitimation (and mutualism in general) are more fluently transmitted across the internal boundaries of social systems than the effects of competition (cf. Hannan *et al.*, 1995c). Finally, the present study also addresses the calls from recent research for increased attention towards the *co-evolution* of organizational populations and their endogenous environments (Aldrich, 1999: 38; Amburgey *et al.*, 1996; Lomi *et al.*, 2005; March, 1994).

The present study also has implications to policy-making, collective industrial action and management practice. To promote the development of an emerging field with strong diversity and internal synergies such as biotechnology and nanotechnology (cf. Hung *et al.*, 2006), supportive governmental intervention should avoid excessive focus on a specific sub-sector. By allowing or even promoting diversity, policy-making can foster the positive effects on organizational entry stemming from mutualistic interdependencies between diverse organizational sub-forms. Too much focus on a specific sub-sector could constrain the positive cross-effects of legitimation and, at the same time, emphasize the constraining, competitive forces within an individual sub-sector. Government intervention also has the ability to help by removing constraints from the resource space faced by the organizations, thus alleviating unnecessary competitive effects. In biotechnology, such resource constraints could be related to e.g. financing options and models, feedback to technology from basic research, educated people, as well as the general public attitude. The findings also indicate that collective industrial action (industry associations, bodies and committees, general industry communication, etc.) may play a major role in promoting the cross-effects of legitimation across the field at various levels (cf. Aldrich *et al.*, 1994). Similarly, management practice can be advised (i) to follow strategies and forms that have generally been legitimized, (ii) to avoid low-legitimation-high-competition traps, as well as (iii) to take deliberate action to boost the legitimation of the field in general.

The rest of the dissertation is structured as follows. Chapter 2 reviews the relevant parts of the organizational ecology literature to develop a general understanding of the core ideas of the ecological approach. The chapter then proceeds to discuss the concepts of organizational population and organizational form. Thereafter, the identity approach to organizational forms is reviewed, the complexity dimension of forms is defined, and the systems approach to organizational forms is elaborated. Finally, the basic formulation of the density-dependence theory is reviewed. Chapter 3 proceeds to derive hypotheses regarding density-dependent processes of organizational entry in heterogeneous populations characterized by complex organizational forms. Chapter 4 provides a detailed description and analysis of the Finnish modern biotechnology industry, including its historical evolution, institutional environment, as well as the underlying sub-forms. Chapter 5 describes the data, methods, and modeling framework used in testing the hypotheses. Chapter 6 presents the results of the statistical analysis. Finally, chapter 7 discusses the extensions and contributions to existing theory and research, as well as the implications on policy-making, collective industrial action, and managerial practice. Also the methodological implications and limitations of the study are discussed, and recommendations for future research are proposed. The chapter concludes with a summary of the results and implications of the study.

2 Theoretical Background

The present study is motivated by two key areas of interest. First, the attention is on population-level mutualistic and competitive processes that guide organizational entry and thus large-scale organizational evolution. Second, the study seeks to contribute to the understanding of organizational diversity and, in particular, what implications such diversity has on the above processes of organizational evolution. The domain of organizational ecology is chosen as the conceptual and methodological basis, with density dependence as the focal theoretical framework.

Organizational ecology and density dependence theory focus on the evolution of organizational populations over long time spans. Thus, the population is a focal unit of analysis. Populations are spatially and temporally bounded groups of organizations whose core properties are similar and who respond similarly to forces stemming from their common environment (Hannan *et al.*, 1989: 45). The carrying conceptual idea is that all members of a population share a common organizational form. Forms are again related to the concept of niche, which is defined as the set of social, economic, and political resources and conditions from the environment that are required for organizations representing a particular form to persist (Hannan *et al.*, 1977).

In addition to the field's theoretical and methodological coherence (Pfeffer, 1993), the domain of organizational ecology has an extensive body of empirical research covering a wide array of different organizational types and industrial settings. However, much of earlier empirical research has focused on relatively simple, product market driven populations with uniform organizational forms (cf. Hsu *et al.*, 2005). Moreover, the choice of empirical populations has thus far featured weak linkages to the concept of organizational form – possibly due to the existing ambiguity and disagreement regarding the theoretical underpinnings of the concept. Fortunately, the recently emerged identity approach (Polos *et al.*, 2002) has brought additional tools to conceptualize and operationalize forms. In particular, the related concept of form complexity (Hsu *et al.*, 2005; Zuckerman *et al.*, 2003) enables one to turn attention to form-related *organizational heterogeneity* within populations.

The present study sketches a systems approach to capture such form complexity and related population heterogeneity. The systems approach is built on the premise that collective organizational identities can be hierarchically nested, forming systems of organizational forms (cf. Carroll *et al.*, 2000a: 69, 76; McKendrick *et al.*, 2001). Such systemic structures are mirrored to empirical populations, capturing related heterogeneity. The systems approach will be used in conjunction with existing density-dependence theory to formulate hypotheses regarding how processes of legitimation and competition affect entry in heterogeneous populations characterized by complex organizational forms.

Based on the above background, the purpose of the present chapter is to review the core ideas, assumptions, and concepts behind organizational ecology and density dependence theory, and to lay down the conceptual backbone of the systems approach to be used in deriving the hypotheses. The remainder of the chapter is organized as follows. First, the intellectual roots and fundamental assumptions behind the domain of organizational ecology are reviewed. This is followed by a short review of the body of related empirical work, putting emphasis on the nature of empirical populations investigated. The following section then turns to reviewing the two fundamental concepts, the population and the organizational form. This is followed by a review of the conceptual ideas behind the identity approach to organizational forms. Next, the attention is turned to complex organizational forms. Thereafter, the systems approach to complex forms is sketched and elaborated. This is followed by a review of the baseline density-dependence theory. Finally, the chapter closes with a review of extant critique towards the domain of organizational ecology and density dependence theory in particular.

2.1 Organizational Ecology: Intellectual Roots and Core Assumptions

The word *ecology* is derived from the Greek word *oikos* which means a house or place to live in. Ecology is commonly defined as "the relation of organisms or groups of organisms to their environment" (Hawley, 1950: 3). The domain of *organizational ecology* focuses on organizational diversity and organizations' relationships to their exogenous and endogenous environments, and seeks to understand the macrosociological processes by which large-scale organizational transformation and evolution unfolds (Hannan *et al.*, 1989: *xi-xvi*). Organizational ecology has its intellectual roots in the fields of sociology and human ecology (Hawley, 1950, 1968), as well as the natural-open-systems perspective in organization theory (Scott, 2003: 108). Organizational ecology shares ideological roots with several adjacent fields of organization theory, most notably the neo-institutional theory (DiMaggio *et al.*, 1983; Meyer *et al.*, 1977; Meyer *et al.*, 1983) and the resource dependence theory (Pfeffer *et al.*, 1978). An overarching theme across the above fields is the environmental influence over organizations. Organizational ecology is also intellectually linked to general evolutionary theory which regards variation, selection, and retention as the three key processes guiding organizational evolution (Aldrich, 1999: 43-45; Hannan *et al.*, 1989: 17-23).

Carroll and Hannan (2000a: 31) provide a useful framework to explain the general structure of ecological explanations of social structure and change (see Figure 1 below). The large-scale social macrostructure is explained by the system of organizations decomposed into individual organizational populations. The dynamics of organizational populations is explained primarily by vital rates (entries and exits of organizations to/from populations), which are again explained by exogenous environmental conditions (such as carrying capacity and external shocks) and endogenous population dynamics (such as population density). Finally, in the long run, outcomes to the general social structure have feedback effects on the exogenous environmental conditions.

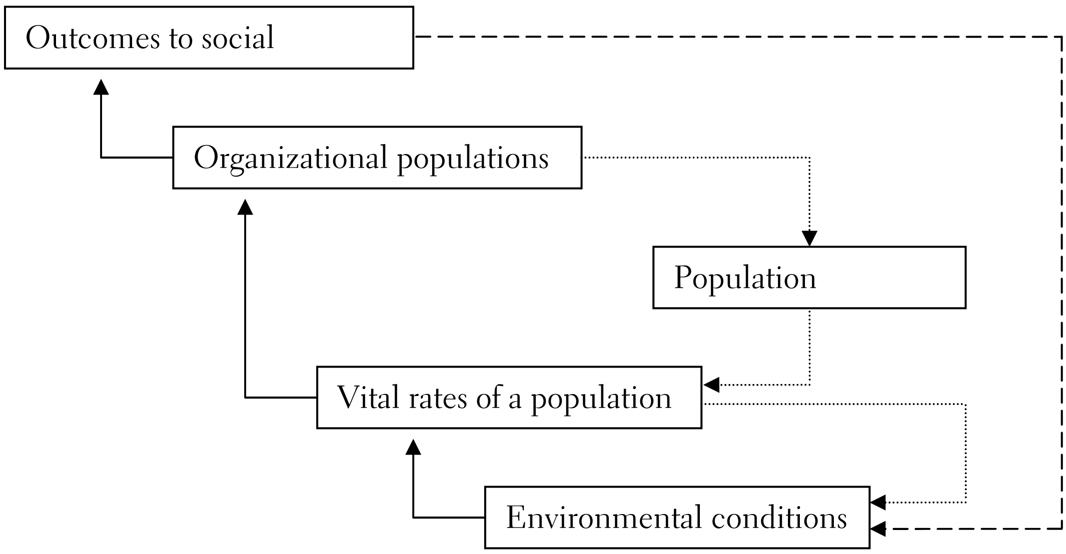

Figure 1: A Structure of Ecological Explanations[3]

A fundamental assumption is that organizations are relatively inert to change, and thus large-scale change in the organizational landscape is driven by evolutionary selection rather than organization-level adaptation (Hannan *et al.*, 1977, 1984). Because of several internal and external "pressures" (Hannan *et al.*, 1977), and early imprinting (Stinchcombe, 1965), it is very difficult and slow for organizations to change their core properties. This characteristic is common to virtually all organizations, and is called structural inertia (Hannan *et al.*, 1977, 1984). This means that even though organizations are to some extent capable of transforming themselves and adapting to environmental change, they are on the average not capable of doing so with the same relative speed as the environment changes. Therefore, the fit between organizational properties on the one hand, and the resources and social demands of the organizational environment on the other, is essentially attained in the long run by a selection and replacement process at the level of whole organizations. In this macrosociological

[3] Adapted from: Carroll & Hannan, 2000: 31.

process, less fit organizations are forced to exit the population and new, fitter organizations are capable of entering. In other words, on the large scale, organizational populations emerge, change, and even die out not because of existing members of the populations flexibly transforming their core properties and thus promptly adapting to environmental change, but because of external selection processes introducing new organizations and even populations to replace existing ones with time (Carroll *et al.*, 2000a; Hannan *et al.*, 1977, 1989).

As Figure 1 points out, organizational ecology seeks to explain dynamics within and across organizational populations, instead of the properties and evolution of individual organizations. Much of social structures in contemporary societies is concentrated to the organizational world, and organizations are generally seen as "the fundamental building blocks of modern societies and the basic vehicles through which collective action occurs" (Aldrich, 1999: 5). Thus, the diversity in the organizational field strongly reflects the diversity in the overall social system (Hannan *et al.*, 1977, 1989). As Hannan & Freeman (1977) point out, not all effects and events at the population level can be reduced to the level of individual organizations. Thus, taking a population approach to studying organizations is of special interest.

A population is generally defined as a spatial-temporal instantiation of an organizational form (Hannan *et al.*, 1977). In other words, all organizations within a population share the same organizational form, and are thus considered as fundamentally similar. An organizational form generally refers to "those characteristics of an organization that identify it as a distinct entity and, at the same time, classify it as a member of a group of similar organizations" (Romanelli, 1991). Organizations sharing the same form have similar core structures and occupy the same niche of resources within their environments (Freeman *et al.*, 1983). Such core structures can be e.g. the product market served, stated goals, forms of authority, and core technology (Hannan *et al.*, 1984). Forms are socially constructed and are used in identifying organizations that are ecologically similar (Aldrich, 1999: 37, 47). Much controversy still exits regarding the theoretical underpinnings of the concept of organizational form, and an unifying definition has yet to fully emerge (cf. McKendrick *et al.*, 2003; Romanelli, 1991).

Organizations have many dependence relationships to other organizations and other social units. There are also several material aspects that are external but vital to organizations. Thus, organizations are viewed as highly dependent on their environments (Pfeffer *et al.*, 1978). The social environment of a population consists mainly of other organizations, organizational populations, and organizational communities (Hannan *et al.*, 1989: 91). The effects imposed by the other members within a population are called endogenous while all other effects are exogenous to the focal population (Carroll *et al.*, 2000a: 193). Besides other populations, exogenous environments also include resources, institutions, technology, and political forces. First, resources refer to both physical and social resources that are somehow used as inputs to an organization's activities in generating its outputs. Creating an organization requires the mobilization of various kinds of resources such as capital, members (i.e. labor), technological knowledge, and legitimation (Hannan *et al.*, 1984; Stinchcombe, 1965). In addition, consumer wealth can be considered as an important resource for organizations (Carroll *et al.*, 2000a: 198). Indeed, without demand for products, services, or some other comparable outputs, the modern organization would generally have very limited chances of survival. The availability of resources from an environment can be seen as a function of (i) the existence of the resources, as well as the (ii) contestability of the resources, i.e. how much of the resources are controlled by other organizational actors.

Second, the exogenous social environment also includes regulative institutions (rules and governance structures imposed by e.g. the legal system), normative institutions (socially shared values and beliefs, and social obligations and sanctions thereof), and cultural-cognitive institutions (common symbolic systems and shared meanings, taken-for-grantedness) that place external demands for organizations (cf. Meyer *et al.*, 1983; cf. Scott, 2003: 135). Third, technological knowledge and innovation is a resource that generally fuels most organizational activity. Technological development can generally be divided into breakthrough innovation and continuous improvement (Klepper *et al.*, 1997; Tushman *et al.*, 1986; Tushman *et al.*, 1998). Finally, effects of the political environment consist of (i) disruptive social revolutions and political crises whereby class and political structures are destroyed and rebuilt, and (ii) continuous, institutional effects such as routine legislative and regime change (Carroll *et al.*, 2000a: 199). As an example, Dobrev (2001) has examined the differing effects between "institutional politics" and "political turmoil" on founding rates in the Bulgarian newspaper industry. He found strong support for the argument that these two types of exogenous political situations have opposing effects of organizational founding.

Organizational environments are generally regarded as diverse, discontinuous and unstable (Hannan *et al.*, 1989: 13). The diversity and discontinuity results in special combinations of environmental resources and conditions called *niches* (Hannan *et al.*, 1977). A niche consists of the "social, economic, and political conditions that can sustain the functioning of organizations that embody a particular form" (Hannan *et al.*, 1995a: 34). Thus, niches and organizational forms are fundamentally related. The organizations that share a common form (e.g. the members of a population) are dependent on a common material and social environment (i.e. niche) and thus are affected homogeneously by forces stemming from the environment (Hannan *et al.*, 1989: 45). Theories of niche width (Freeman *et al.*, 1983; Hannan *et al.*, 1977) and fitness-set (Levins, 1968) attach a fitness function to environmental niches that determines how the resource levels of a niche affect population growth rates, i.e. how the organizations within a population are dependent on their shared niche or resource space. The concept of niche is central to ecological analyses of competitive effects within an organizational population, in most empirical cases between generalist and specialist organizations (Carroll, 1985). Just as animals compete for food in biotic populations, organizations within a population compete for various types of resources from their shared niche. Thus niches have a *carrying capacity*, i.e. the maximum amount of organizations that the current (constrained) resource base can sustain (McPherson, 1983).

The concept of *isomorphism* is also important regarding organization-environment relationships. Isomorphism refers to the commonly observed process by which organizational units subject to the same environmental conditions will acquire a similar form of organization (Hawley, 1968). This is equivalent to the fit between an organizational form and the related niche where organizations representing the form can arise and persist.

Environmental instability and structural inertia of organizations is a combination that favors environmental selection and replacement processes in governing organizational diversity and change. According to the original formulation by Hannan and Freeman (1977), it is the environment that selects out and thus "optimizes" the combinations or distributions of organizations to best fit the contemporaneously available configuration of resources. A similar idea was proposed already by Stinchcombe (1965), who suggested that the array of organizational forms existing at any point in time is a product of innovative organizational responses to environmental conditions in the past.

The above intellectual roots and key assumptions of organizational ecology are summarized Table 1 below.

Table 1: Core Assumptions and Intellectual Roots of Organizational Ecology

Focal area of interest	Organizational diversity and large-scale change over long time spans. Organizations' relationships to their endogenous and exogenous environment.
Unit of analysis	Organizational populations and forms.
Organizational assumption	On the average, organizations are inert, i.e. incapable of transforming and adapting themselves fast enough relative to the speed of environmental change. A limited number of organizational forms exist, along which organizations and organizational properties are distributed. Populations are spatial-temporal realizations of (abstract) forms. All members of a population share the same organizational form and are thus fundamentally homogeneous.
Environmental assumption	Environments are generally diverse, discontinuous, and unstable. Organizational environments consist of social, economic, and political conditions that enable organizations to arise and persist. Specific, bounded sets of environmental resources and conditions are called niches. Within niches, material resources are limited. Carrying capacity measures the maximum number of organizations that a niche can sustain.
Organization-environment relationship	Organizations are highly dependent on the social and material aspects of their environments. Organizational forms and environmental niches are fundamentally related and have isomorphic configurations. Those organizations that are most fit with a specific niche (and thus form) have the best probability of survival. The members of a specific form respond similarly to forces stemming from their common environment.
Key mechanism driving change in the organizational domain	The process of environmental selection and replacement results in dynamic distributions of organizations and organizational forms adapted to contemporaneous environmental configurations.
Intellectual roots	Sociology, human ecology, the natural-open-systems perspective to organizations, neo-institutional theory, resource dependence.

The emergence, diversity, and evolution of organizational populations is explained through various processes at the population and organization level (see useful reviews e.g. in Amburgey *et al.*, 1996; Baum, 1996; Carroll *et al.*, 2000a; Singh *et al.*, 1990). Key population level processes include *density dependence*, including its several additions and specifications, *resource partitioning*, and *size-localized competition*. Key organization level processes include different *age-dependent processes* and *size dependence*. Table 2 below presents a list of these key ecological processes, a short description of each, their key concepts and mechanisms, and examples of related research. As noted above, the present study focuses on density dependence as the focal theoretical framework.

A final note concerns the relationship between the fields of organizational ecology and industrial economics, the *industrial organization (IO)* and *evolutionary economics* perspectives in particular. Several commonalities exist, such as the attention to the size and structure of populations (or "markets" or "industries"), processes of population level change and evolution, resources and environments, the processes and outcomes of competition, specialization, and so on (Geroski, 2001; Van Witteloostuijn *et al.*, 2006).

Table 2: Key Ecological Processes

Ecological processes	Short description	Key concepts & mechanisms	Examples of related research
Population processes			
Density dependence	Legitimation and competition are two key mechanisms that have opposing effects on organizational entry and exit rates within a population. The levels of legitimation and competition vary with the density of a population, thus connecting population density to the vital rates. Several extensions have been developed to make the models more accurate.	Legitimation, competition, density delay, temporal heterogeneity, spatial heterogeneity, size interactions	(Cattani *et al.*, 2003; Dobrev, 2001; Greve, 2002a; Hannan, 1986, 1997; Hannan *et al.*, 1995c; Wezel, 2005)
Resource partitioning	As a population matures, the strongest competition for resources gets concentrated between a small number of generalist organizations positioned in the market centre. This crowding may free up uncontested resource niches in the market periphery for specialist organizations. This shows as a late resurgence (decline) in entry (exit) rates of specialist organizations.	Specialist vs. generalist organizations, concentration & crowding, resource space & niche width, market centre vs. periphery	(Boone *et al.*, 2000; Carroll, 1985; Carroll *et al.*, 2000b; Dobrev, 2000)
Size-localized competition	Organizations with similar size have similar strategies and thus mainly compete with organizations with similar size. This typically leads to bimodal size distributions where very small and very large organizations may coexist within a population.	Competition, organizational size distributions	(Baum *et al.*, 1992a; Hannan *et al.*, 1977; Hannan *et al.*, 1990; Ranger-Moore *et al.*, 1995)
Organizational processes			
Age-dependence	A combination of explanations that relate organizational age to their vulnerability to environmental change and thus their survival chances. Concentrates on mortality rate analysis.	Liabilities of newness, adolescence, obsolescence, and senescence, imprinting & structural inertia, capabilities & positional advantages	(Barron *et al.*, 1994; Brüderl *et al.*, 1990; Fichman *et al.*, 1991; Henderson, 1999)
Size-dependence	A combination of explanations that relate organizational size (and similar measures) to their survival chances. Concentrates on mortality rate analysis.	Organizational size, mass, capacity, and scale, liability of smallness	(Barnett *et al.*, 1994; Baum *et al.*, 1992a; Carroll *et al.*, 1996; Edwards *et al.*, 1995; Ranger-Moore, 1997)

However, perhaps the most profound difference between organizational ecology and the economics-based perspectives relates to the underlying logic in explaining what drives organizational change. Organizational ecologists argue that long-term, large-scale changes in the composition and diversity of organizational populations is driven by processes of environmental *selection* and replacement, instead of organization-level *adaptation* and transformation which is central to economics (Carroll, 1988: 2). The underlying idea is that the properties of and changes in the material and social environments of organizations strongly affect the characteristics, creation, and survival of organizations. In order to survive, organizations must be relatively well in fit with the resources available in and the social demands originating from their environments. Less fit organizations have lower chances of survival than more fit ones. Moreover, ecologists view organizational environments as predominately unstable and discontinuous, and thus find the concept of equilibrium – central to the field of economics – somewhat dysfunctional (cf. Hannan *et al.*, 1989: 25). This also means that being fit with the environment is not a stable state. That is, less fit organizations may become more fit with time, and vice versa.

This view has somewhat opposed the more conventional organization and management theories that build on the idea that organizations are rational actors with unitary organizational preference structures and the ability to promptly adapt to environmental changes (cf. Baum, 1996). Supporting the domain of organizational ecology, many studies have indeed shown that the same organizations – even the leading ones – very seldom retain their dominance or even survive as the surrounding environmental structures change in the long run (cf. Hsu *et al.*, 2005). Several fundamental factors indeed limit the ability of managerial actions to effectively transform existing organizations to match environmental change. First, researchers of organizational forms (e.g. Hannan *et al.*, 1977; Romanelli, 1991) and strategic groups (e.g. McGee *et al.*, 1986; Reger *et al.*, 1993) have noted that organizational action and choice is limited by e.g. control/incentive systems, shared norms, and social pressure and sanctions imposed by the organizational environment and the group of similar organizations that the focal organization belongs to. Second, the scarcity of resources and dependence on existing resources limits core transformation (Pfeffer *et al.*, 1978). Third, the competitive dynamics within and between organizational populations limits managerial choice (e.g. Hannan *et al.*, 1989, p. 41). Finally, the bounded rationality in administrative behavior is also limiting factor in successful organizational adaptation (e.g. Simon, 1997).

2.2 Empirical Work in Organizational Ecology

Empirically, organizational ecology resembles demographic research in many ways (Carroll *et al.*, 2000a; Hannan *et al.*, 1989; Hsu *et al.*, 2005). Several conspicuous characteristics typify empirical research in organizational ecology. First, the focus is on studying individual industries or populations, as opposed to cross-sectional studies across a variety of industries and organizational forms. Second, the interest is on complete life histories of a particular industry, including data on all organizations in the population over its entire history. Third, much of the formal modeling is built on the vital rates of organizational populations. This requires the researchers to record detailed information on the types of entries and exits of organizations to/from the population over the whole life-span of the population. Fourth, because of the focus on historical events and the specification of vital *rates*, a key property of ecological research is the presence of some demographic clock (Carroll *et al.*, 2000a: 109) that is used to measure organizational and population tenure, as well as to establish time-links between individual events. Fifth, event-history based models are used to estimate organization, population and environmental effects on the hazards of entry and exit. For failure or exit, it is possible to model and estimate organization-level hazards. However, hazards of founding or entry have to be specified on the population level because the nonoccurrence of events (entries) cannot by definition be associated to any single organization and its characteristics (cf. Carroll *et al.*, 2000a; Hsu *et al.*, 2005). Despite the organizational population being the basic unit of analysis, properties of the individual members of a population – such as founding time, survival time, specialization, and size – are thus also central measures in the empirical investigations of ecological theory.

The existing body of ecological studies is relatively large and covers a wide array of industrial settings. A simple search within 13 selected journals that have actively published ecological research results in some 400 hits between 1986 and 2006, of which approximately half are full-length articles within the domain of organizational ecology[4]. Table 3 below shows 116 selected empirical works that have been categorized by their industrial context.

Table 3: A List of Empirical Studies in Organizational Ecology 1986-2006

Population	Empirical studies
Auditor/accounting firms	(Boone *et al.*, 2000; Boone *et al.*, 1995; Cattani *et al.*, 2003)
Automobile manufacturers	(Bigelow *et al.*, 1997; Carroll *et al.*, 1996; Dobrev *et al.*, 2003; Dobrev *et al.*, 2002; Dobrev *et al.*, 2001; Hannan, 1997; Hannan *et al.*, 1998a; Hannan *et al.*, 1998b; Kim *et al.*, 2003; Sorenson, 2000)
Banks, loan providers, credit unions	(Barnett *et al.*, 1994; Barnett *et al.*, 1996; Barnett *et al.*, 2002; Barron, 1998, 1999; Barron *et al.*, 1994; Greve, 2000, 2002a; Hannan *et al.*, 1995c; Lomi, 1995a, 1995b, 2000; Ranger-Moore *et al.*, 1991; Rao *et al.*, 1992; Sinha *et al.*, 1997)
Baseball teams	(Land *et al.*, 1994)
Biotechnology industry	(Oliver, 2001; Silverman *et al.*, 2002; Sorensen *et al.*, 2000; Stuart *et al.*, 2003)
Brewing industry	(Barnett, 1997; Boone *et al.*, 1995; Carroll *et al.*, 1993; Carroll *et al.*, 2000b; Carroll *et al.*, 1991; Lubatkin *et al.*, 2001; Swaminathan, 1996, 1998; Swaminathan *et al.*, 1991b; Wade *et al.*, 1998)
Day care centers	(Baum *et al.*, 1992b, 1996a; Baum *et al.*, 1994a, 1996b)
Disk drive manufacturers	(McKendrick *et al.*, 2001; McKendrick *et al.*, 2003)

[4] Academy of Management Journal, Academy of Management Review, Administrative Science Quarterly, American Journal of Sociology, American Sociological Review, Annual Review of Sociology, European Sociological Review, Industrial and Corporate Change, Organization Science, Organization Studies, Social Forces, Social Science Research, and Strategic Management Journal. Search performed on May 15th, 2006.

Film industry	(Mezias *et al.*, 2000; Mezias *et al.*, 2005)
Footwear production	(Sorenson *et al.*, 2000)
Healthcare organizations & associations	(Clarke *et al.*, 1992; Galvin, 2002; Ruef, 2000; Wholey *et al.*, 1992)
Hotels	(Baum, 1995; Baum *et al.*, 1997; Baum *et al.*, 1992a; Ingram, 1996; Ingram *et al.*, 1997a, 1997b; Ingram *et al.*, 1996)
Insurance firms	(Budros, 1992, 1994; Ranger-Moore, 1997; Ranger-Moore *et al.*, 1995)
Labor unions	(Hannan *et al.*, 1987, 1988; Ranger-Moore *et al.*, 1991)
Motorcycles	(Wezel, 2005)
Newspapers	(Amburgey *et al.*, 1993; Barnett *et al.*, 2004b; Boone *et al.*, 2002, 2004; Carroll *et al.*, 1989b; Carroll *et al.*, 1986; Dacin, 1997; Dobrev, 2000, 2001; Levinthal, 1991; Miner *et al.*, 1990; Swaminathan, 1996; West, 1995)
Power production	(Russo, 2001)
Gasoline retail stations	(Usher *et al.*, 1996)
Semiconductor, microprocessor & personal computer producers	(Barnett *et al.*, 2001; Henderson, 1999; Podolny *et al.*, 1996; Wade, 1995, 1996)
Social movement organizations	(Edwards *et al.*, 1995; Minkoff, 1994, 1997; Olzak *et al.*, 2001; Ruef, 2004; Sandell, 2001; Simons *et al.*, 2003; Stern, 1999; Weed, 1991)
Symphony orchestras	(Allmendinger *et al.*, 1996)
Telecommunication firms	(Barnett, 1990, 1997; Barnett *et al.*, 1987; Baum *et al.*, 1995a)
Television/radio producers & stations	(Greve, 1995, 1996, 1998, 2002b; Sorensen, 1999)
Trade unions	(Hedstrom, 1994; Sandell, 2001)
Wineries	(Delacroix *et al.*, 1991; Delacroix *et al.*, 1989; Swaminathan, 1995, 2001; Swaminathan *et al.*, 1991a)
Worker cooperatives	(Ingram *et al.*, 2000; Simons *et al.*, 2004; Staber, 1989)

A conspicuous feature of Table 3 is that existing empirical work in organizational ecology seems to have generally focused on relatively homogeneous populations with simple organizational forms, often defined grossly through salient product markets and/or pre-existing industrial categories (cf. Hsu *et al.*, 2005). Banks (Greve, 2002a; Lomi, 1995a, 2000), automobile producers (Dobrev *et al.*, 2001; Hannan, 1997;

Hannan *et al.*, 1995c), hotels (Baum *et al.*, 1997; Baum *et al.*, 1992a; Ingram *et al.*, 1996), and newspapers (Carroll *et al.*, 1989b; Dacin, 1997; Dobrev, 2001; Miner *et al.*, 1990) are good examples of populations which are strongly bounded by product markets and hold relatively simple and uniform organizational forms. Recent research has questioned this focus in extant empirical research, and stressed the need to include more complex settings where organizational forms are not directly linked to salient product markets (Hsu *et al.*, 2005; McKendrick *et al.*, 2001).

In addition, despite a relatively good overall support (Carroll *et al.*, 2000a: 218), a number of studies have found mixed results for density dependence theory in specific empirical settings. For example, Barnett and Amburgey (1990) found opposite effects between density and entry for the population of telephone companies in Pennsylvania. Similarly, McKendrick et al (McKendrick, 2001; McKendrick *et al.*, 2001; McKendrick *et al.*, 2003) have found mixed results for disk array producers. Finally, studies of the Dutch accounting industry have found disconfirming results for standard density-dependence theory (Boone *et al.*, 2000; Pennings *et al.*, 2002). Both telephone companies and disk drive producers represent technology driven industries where product markets and organizational forms are diverse and in constant flux. As McKendrick and Carroll (2001) note, disk arrays represent a clear product class, but not necessarily an organizational form of its own. Instead, the producers of disk arrays represent a diverse set of organizations with a multitude of industrial backgrounds and varying levels of size and specialization. As for the Dutch auditing industry, Cattani et al (Cattani *et al.*, 2003) have found that the heterogeneous population is divided into 11 sub-populations according to the geographically distributed provinces within the country. Each geographical sub-population faces a distinct selection environment, thus affecting the predictions of density-dependent entry.

These findings further emphasize the importance of turning increased attention to more heterogeneous populations. In addition, the product market seems not always to be the proper basis for defining the organizational forms for empirical populations. In the other hand, it is also true that simple product-market driven forms, such as automobiles and hotels, are abundant in the organizational domain, and have provided a fertile ground for the initial development of ecological theory. Thus the early theoretical work has also emphasized population homogeneity, as noted in the following section.

2.3 Organizational Populations and Forms

Starting from the early formulations, organizational ecology has held the view that the members of an organizational population are homogeneous in terms of their core properties and environmental vulnerability (Hannan *et al.*, 1977, 1989). This view follows directly from the general definition of the concept of organizational population, according to which populations are (i) spatially and temporally bounded groups of organizations that are (ii) characterized by a particular organizational form and (iii) dependent on a common set of material and social resources from their environment (Carroll *et al.*, 2000a: 59, 65). Thus populations have structural properties and social boundaries such that they can be distinguished from the members of other organizational populations (Carroll *et al.*, 2000a: 59). In addition, being dependent on the same resource space means that the members of a population are similar in terms of how they are affected by environmental variation (Hannan *et al.*, 1977, 1989: 45).

Consider the premise that populations are bounded in time and space. First, being dependent on the same resource space usually means that the members of a population are geographically concentrated. For example, the automobile manufacturers in the United States represent a different population than the automobile manufacturers in Germany. The resource space – demand for vehicles, raw materials, suppliers, skilled employees, legislative constraints, social environment, competing populations, etc. – is clearly different in both instances. Second, organizational populations are also bounded in time. If, for example, the automobile manufacturer population in a specific region would go extinct and a new one would emerge later on, these would represent two different organizational populations. The effect of prohibition periods on brewery populations is a good illustration of such a case (Carroll *et al.*, 1993).

It follows from the definition of population that the concepts of organizational population and organizational form are fundamentally related. While an organizational form is an *abstract* concept that defines a class of similar organizations, populations are *real* (empirical) "instances" of organizational forms (Hannan *et al.*, 1995a: 29). Thus the specification of meaningful population boundaries requires proper understanding and definition of the underlying organizational form.

While it seems that no coherent and generally accepted definition of the concept of *organizational form* has yet emerged (cf. Carroll *et al.*, 2000a; Hsu *et al.*, 2005; Romanelli, 1991), researchers generally tend to agree on the functional purpose of the concept of form in ecological research. It is generally used to refer to "those characteristics of an organization that identify it as a distinct entity and, at the same time, classify it as a member of a group of similar organizations" (Romanelli, 1991). Additionally, it is generally agreed that forms are socially constructed and are used in identifying organizations that are ecologically similar (Aldrich, 1999: 37, 47). Thus, in essence, the purpose of the concept of organizational form is to identify classes of organizations that are similar in relation to some core elements (e.g. strategy, product-markets, or external identity), but simultaneously are different and unique in terms of peripheral or less core features (e.g. composition of internal members, facilities, or organizational size).

Organizational forms have been exemplified by the rational-legal bureaucracy (Weber, 1968), for-profit corporations vs. non-profit arts organizations (Johnson *et al.*, 2006), biotechnology firms (Baum, 1999), breweries (Hannan *et al.*, 1995a: 29), and even pizza places (Romanelli, 1991). All of these define a specific class of organizations that share some central commonalities (product market, forms of authority, technology, etc.) but can be different and unique in terms of less central properties (size, location, members, etc.).

In their early conception of the principles of organizational ecology, Hannan and Freeman (1977) defined an organizational form as a "blueprint for organizational action, for transforming inputs into outputs". Such "blueprints" are essentially defined by characteristics such as "formal structure, patterns of activity and normative order" (Hannan *et al.*, 1977). A little later, the definition was made somewhat more specific, yet still focusing on more or less structural and observable aspects of organizations. According to Freeman & Hannan (1983), organizations sharing the same form have similar core structures and occupy the same niche of resources within their environments. Such core structures can be e.g. (i) the organization's stated goals, (ii) forms of authority, (iii) core technology, (iv) as well as customer base (Hannan *et al.*, 1984). In this definition, the relationship to the organizational environment, and the distinction between core and peripheral features gets emphasized. The latter further underscores that, while belonging to a recognizable set of similar organizations, the definition of the form allows for individual organizations to also possess unique characteristics.

In a related vein, researchers of organizational taxonomy and classification have made use of the concept of *organizational species* defined as "polythetic groups of competence-sharing populations isolated from each other because their dominant competencies are not easily learned or transmitted" (McKelvey, 1982: 192). According to McKelvey and Aldrich (1983), populations defined by such species have the properties of (i) similarity of members, (ii) sharing of replication materials and competencies across the population, and (iii) no sharing between different populations. The taxonomists have even aimed at developing rather stable classification systems for organizations. This differs from the ecologists' view that no such stable and universal classifications are possible or even relevant, for that matter (cf. Romanelli, 1991).

The above early definitions of the concept of organizational form belong to a class of definitions that Carroll and Hannan (Carroll *et al.*, 2000a: 60) label as "trait-based". Such definitions see organizational forms as clusters of features, some of which are core and others peripheral. This relates also strongly to the idea that changes in organizations' core features have a negative effect on their chances of survival (Hannan *et al.*, 1984). Thus, just as the principles of isomorphism and structural inertia predict, organizations tend to adhere to the existing form within the populations and thus keep core features similar to other population members. However, since changes in the peripheral features don't have such effects on survival, the organizations under the same form may vary from each other along this dimension.

Another class of definitions approach the concept of organizational form through social boundaries (Carroll *et al.*, 2000a: 62). In this vein, organizations are also seen as clusters of features, but the existence and location of socially identifiable boundaries between different forms matters more than the clustered features per se (Hannan *et al.*, 1986). Processes that create and maintain such boundaries include social network ties, flows of personnel between the organizations in a population, technological discontinuities, social movements and simply geographical boundaries. A third class of definitions of organizational form relate to network ties. In other words, if two organizations have similar relationships to key actors and resources in their environments, they can be considered as structurally equivalent (Carroll *et al.*, 2000a: 63).

As noted in the earlier sections, organizational forms (and thus populations) are also related to the concept of niche. Niches are sets of environmental resources that "consist of the social, economic, and political conditions that can sustain the functioning of organizations that embody a particular form" (Hannan *et al.*, 1995a: 34). The organizations that share a common form (e.g. the members of a population) are dependent on a common material and social environment and thus are affected homogeneously by forces stemming from the environment (Hannan *et al.*, 1989: 45).

Summarizing, organizational populations are spatially and temporally bounded groups of similar organizations. The members of populations share a common organizational form, which means that they have similar core properties and are dependent on the same set of resources from their environmental niche. Thus the organizations are homogenously affected by environmental variation. Forms are central in defining empirical populations, but disagreement exists regarding the definition and conceptual underpinnings of the concept of form.

Surprisingly, a majority of the extensive body of empirical work in organizational ecology has not explicitly applied the concept of organizational form in defining empirical populations (cf. McKendrick *et al.*, 2001). As noted in the previous section, empirical populations often follow conventional industry or product-market categories. This has lead to a focus on relatively homogeneous populations with uniform organizational forms. The origins of the prevailing focus can be traced to both the high level of abstraction and fragmentation of the early conceptual work in organizational forms (cf. Hsu *et al.*, 2005; McKendrick *et al.*, 2001; Polos *et al.*, 2002; Romanelli, 1991), as well as the overarching original idea that the members of a population should be more or less homogeneous.

To increase the conceptual robustness of the field, a new strand of theorizing has recently emerged to explain organizational forms through socially recognizable organizational identities (see e.g. Baron, 2004; Carroll *et al.*, 2000a; Hsu *et al.*, 2005; McKendrick *et al.*, 2001; McKendrick *et al.*, 2003; Polos *et al.*, 2002; Ruef, 2000). The identity based approach is the most recent and perhaps most promising endeavor of defining organizational forms. Following a logic similar to the social boundaries view, the identity based approach sees an organizational form as a cultural object. A form is a recognizable pattern that takes on a rule-like standing, an externally enforced identity (Carroll *et al.*, 2000a, p. 67; Hsu *et al.*, 2005; McKendrick *et al.*, 2003). A detailed review of the identity-based approach to organizational forms and its research implications are presented in the following section.

2.4 The Identity Approach to Organizational Forms

The purpose of this section is to review the fundamental principles of the identity approach to organizational forms. The formal-theoretical conception of the role of organizational identities in defining organizational forms formulated by Pólos et al. (2002) can be regarded as one of the most fundamental formal accounts in this vein thus far. Hsu & Hannan (2005) present a comprehensive review of their core ideas as well as the application of these ideas in the domain of organizational ecology. Unless indicated otherwise, the ideas presented in the remainder of this section are based on the above sources.

Different social agents, both internal and external to organizations, hold assumptions, beliefs, and expectations about an organizational domain as well as the individual organizations within the domain. Relatively homogeneous sets of such agents are called *audiences*. By definition, audiences consist of agents that have control over material and symbolic resources that affect the success and failure of the members in the related organizational domains.

Organizational identity refers to a set of *social codes* or *rules* about the default features or actions (or constraints thereof) that different audiences expect an organization to possess/follow. An audience's social approval of an organization depends on how the audience perceives the organization to adhere to or violate the default codes expected by the audience based on the organization's identity. Research has shown that an observed violation of a code generally leads to a decreased valuation of the organization by the audience. Because such feature expectations are tied to evaluations of organizational worth and, as a result, the chances of success and failure, audiences thus have the power to shape organizations through imposing constrains on the features organizations adopt. Hence, organizational identities generally have a rule-like status. Identities set limits on organizational features and action through their inherent social codes.

The above leads to the important notion that the definition of an organization's identity is not based in the organization itself but within the different audiences external to the organization. Thus, this definition of organizational identity differs somewhat from the definition from the domain of organizational behavior whereby organizational identity is essentially seen as something that gets collectively formed by the internal members of an organization. In addition, identity is clearly not based on a list of observable properties of an organization. Thus empirical research cannot measure identity by observing such static properties. Instead, researchers should look into the perceptions, expectations, and actions by relevant organizational audiences to learn about the codes that contemporaneously define the external identity of organizations.

It should also be stressed that an organization can have several different audiences that may have different and perhaps conflicting default expectations for the organization. How much the expectations of various audiences differ from each other essentially defines the ease of acquiring an identity, as well as the sharpness of devaluations related to code violations. Generally, if all audiences hold very similar default expectations, obtaining a clear identity is easy but violations are sharply sanctioned, and vice versa.

How does the concept of organizational identity relate to defining an organizational form, then? An organizational form represents an externally enforced, *collective organizational identity*. In essence, an organizational form is a codified category to which an audience attaches a label and a collective identity in terms of codes regarding what is and is not acceptable for the members of the category. Membership in sociologically real categories constitutes a part of an individual organization's identity. A sociological category is *nominal* if no valuations get associated to its members by audiences. In contrast, for sociologically *real* categories, audiences screen candidate members for conformity with the associated standards before accepting them as authentic members of the category in their eyes.

Once validated as a member, audiences continue to assume that an organization satisfies the membership standards to the category as long as they get no information showing the contrary (i.e. violating the expected codes or rules). Thus, the status of a validated member represents an advantage.

In this conception of the organizational form, the existence of distinct *labels* to categories or forms is an important issue. Labels bring in several advantages to the understanding and formation of organizational forms. First, access to a label helps audiences isolate a particular form from others in the social world. This reflects the effect of linguistic categories on cognition in general. Second, a label emphasizes the homogeneity of the members of a form by focusing attention to similarities and associations between the members. Third, a label also makes forms more available or salient to audiences. Fourth, labels facilitate communication regarding the form and its relation to other actors, forms, and social phenomena.

Finally, as Carroll and Hannan (2000a) point out, an organizational form is a cultural object. Thus it has the capability of preserving in time beyond local populations, and the capacity of spreading over boundaries of social systems such as nation-states. Thus, for example, it has been argued that the sociological-institutional process of legitimation operates on a broader geographical scope than the process of competition for scarce resources (Hannan *et al.*, 1995c).

2.5 Complex Organizational Forms

Despite the original idea of intra-population homogeneity, real organizational populations are often relatively heterogeneous (cf. Cattani *et al.*, 2003). For example, many industries face diverse environments with geographically unevenly distributed resource abundances (Aldrich, 1979; Chandler, 1990; Hannan *et al.*, 1995c; Krugman, 1995). This causes spatial heterogeneity within organizational populations and such heterogeneity has been found to affect the predictions of density dependent entry (Greve, 2002a; Hannan *et al.*, 1995c; Lomi, 1995b, 2000; Wezel, 2005). Populations have also found to be hetefrogeneous in relation to organizational size distributions (Barnett, 1997; Barnett *et al.*, 1990; Barnett *et al.*, 2004a), time (Hannan, 1997; Wezel, 2005), and generalist vs. specialist strategy (Boone *et al.*, 2000; Carroll, 1985; Dobrev *et* *al.*, 2001).

An additional type of heterogeneity is related to organizational forms, i.e. the variance related to the core properties and collective identity of the members of a population. In such cases, a diverse set of organizations may be associated to a specific, broadly defined organizational form. The related organizational populations are often perceived as heterogeneous, as several different types of organizations are included. These organizations can represent several product markets and operate with different business models. At the same time, they hold a common glue such as a technology base. The identity approach provides useful conceptual tools to approach such organizational forms. In particular, the identity approach enables the conceptualization of the *complexity* dimension to organizational forms (Hsu *et al.*, 2005; Zuckerman *et al.*, 2003).

In essence, complexity captures the heterogeneity of organizational properties generally associated to an organizational form and thus the heterogeneity of organizations that are qualified as members. Based on the identity approach to organizational forms, the complexity of an organizational form is defined as the number and diversity of codes associated to the externally enforced, rule-like collective identity of the form (Hsu *et al.*, 2005; Zuckerman *et al.*, 2003). A complex organizational form may have several, disparate audiences that collectively associate a heterogeneous set of organizations (and thus expected organizational properties and behavior) to the form's collective identity and label. In contrast, simple organizational forms have generic, narrowly defined identities and thus are associated to a rather uniform and homogeneous set of organizations. Consequently, the number of relevant audiences as well as the coherency of the different audiences' expectations regarding the identity generally define the complexity of an organizational form. It should also be noted that complexity is not dichotomous (i.e. either simple or complex) but rather a point within a continuum.

Organizational forms defined by product-markets (e.g. automobiles, hotels, or newspapers) clearly represent the simple end of the continuum. By the association to an end product or service, audiences generally have uniform, well defined, and concrete understandings of what such organizations are alike, what they do, and how they behave – and set their expectations accordingly. The same is true for organizational forms that are defined by governmental or other types of authorization (e.g. health maintenance organizations, financial institutions, television and radio stations, telecommunication network operators, labor unions, and accounting firms). Usually such formally authorized organizations also hold quite uniform identities in terms of their product-markets.

On the other hand, organizational forms and identities defined primarily in terms of technology (e.g. semiconductors, software, internet technology, biotechnology) generally reside further away from the simple end of the continuum. For example, the producers of disk arrays (a computer storage technology) have diverse industrial backgrounds, retain simultaneous activities in other industries, and are also otherwise a heterogeneous set of organizations (McKendrick *et al.*, 2001; McKendrick *et al.*, 2003). Moreover, the disk-array technology itself holds several variants and standards and comprises of several different but interconnected technological components. Indeed, one could speak of a *technological system* instead of a single technology (McKendrick *et al.*, 2001). Thus, despite the quite clear product category, different audiences have had difficulty in associating disk-array organizations to a coherent, universal set of codes for validation as members of a possibly distinct form (McKendrick *et al.*, 2001).

Modern biotechnology is a par excellence example of a still more complex organizational form which is not related to a specific product market at all. To start with, biotechnology can today be considered to have a very conspicuous and institutionalized overall identity. For example, the mainstream business press constantly features articles specialized in biotechnology. Additionally, many stock exchanges and other financial institutions constantly quote related indicators (e.g. the NASDAQ Biotechnology index). As a label, biotechnology is also well known to the general public, not least because of the public debate regarding the ethical issues in biotechnology and genetic engineering.

However, biotechnology represents neither a clear-cut product market, a long existing industrial category, nor a formally authorized organizational type. Instead – as the name implies – biotechnology represents an industry whose boundaries are defined by core technology/knowledge (cf. Calabrese *et al.*, 2000). In other words, the biotechnology industry consists of those organizations whose core activities are related to a set of (bio)technologies. This technology-based definition of biotechnology is generally prevalent across various fields of the social sciences, including organization research, economics, and finance (e.g. Calabrese *et al.*, 2000; Lerner *et al.*, 2003; Liebeskind *et al.*, 1996; McKelvey, 1996; Oliver, 2001; Powell *et al.*, 1996; Walker *et al.*, 1997; Zucker *et al.*, 1998).

Generally, biotechnology refers to biochemical and related technologies that enable the development, improvement and production of several types of products and services. Perhaps the most widely accepted formal definition of biotechnology is stated by the Organization for Economic Co-operation and Development (OECD, 2004):

> *"[Biotechnology is defined as] the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or nonliving materials for the production of knowledge, goods and services."*

Another powerful organization, the United States based Biotechnology Industry Organization BIO defines biotechnology as "the use of biological processes to solve problems or make useful products" (Biotechnology Industry Organization, 2006). This corresponds strongly with the OECD definition and clearly shows the technological basis of what is associated to biotechnology. OECD and BIO both also present their lists of core technologies that set the boundaries of biotechnology (see Table 4 below).

Table 4: Definitions of Biotechnology

Source	Definition of Biotechnology	List of Defining Technologies
Organisation for Economic Co-operation and Development OECD (OECD, 2004)	"The application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services"	DNA/RNA based techniques, proteins and other molecules, cell and tissue culture engineering, process biotechnology techniques, gene and RNA vectors, bioinformatics, nanobiotechnology
Biotechnology Industry Organization BIO (Biotechnology Industry Organization, 2006)	"The use of biological processes to solve problems or make useful products"	Bioprocessing technology, monoclonal antibodies, cell culture, recombinant DNA technology, cloning, protein engineering, biosensors, nanobiotechnology, and microarrays

In essence, biotechnology is defined by a broad set of knowledge-based factors of production. This enables related organizations to operate with diverse strategies, business models, and – most notably – in different product-markets (Luukkonen, 2005). Indeed, to capture the underlying organizational heterogeneity, extant research has identified several salient fields of biotechnology, including pharmaceuticals, diagnostics, biomaterials, bioinformatics, industrial enzymes, food and feed, environment/waste management, and agrobiotech (Baum *et al.*, 2000; Hermans *et al.*, 2006a; Luukkonen, 2005; Schienstock *et al.*, 2001; Stuart *et al.*, 1999). These sub-forms tend to more readily center around specific product (or service) markets. In this respect, their organizational forms (i.e. collective identities) are clearly simpler than that of the main biotechnology form. Yet, most audiences associate these sub-forms also as integral parts of the main form (Baum *et al.*, 2000; Hermans *et al.*, 2006a; Liebeskind *et al.*, 1996; Powell *et al.*, 1996; Stuart *et al.*, 1999).

The complexity of the biotechnology form is further increased by its connections to basic scientific research. Biotechnology shares its roots in a diverse set of basic sciences, including chemistry, biochemistry, molecular biology, microbiology, medicine, cell biology, genomics, and biophysics. Biotechnology organizations often have a dual role in connecting scientific research to commercial activities. Besides for-profit firms operating under the above fields, the biotechnology industry is generally characterized with strong networks including organizations like universities, public research organizations and venture capital firms (Powell *et al.*, 1996). Thus the field has a multitude of different audiences with obviously diverse understandings of the underlying default codes that define the identity of the field.

As noted earlier, a look at the extant body of empirical research in organizational ecology reveals that a majority of the studies have concentrated on relatively simple organizational forms. Most of these forms and populations have been defined by product-markets, while only a few represent technology-driven industries. While a few of the studies relate to the biotechnology industry (e.g. Calabrese *et al.*, 2000; Oliver, 2001; e.g. Silverman *et al.*, 2002; Stuart *et al.*, 2003), virtually all of them have narrowed their focus to the field of human therapeutics only (i.e. the application of biotechnology in pharmaceuticals and diagnostics). Only a few studies have paid attention to the variation of the organizational form within populations, as exemplified by the studies regarding the wine (Swaminathan *et al.*, 1991a) and brewing industries (Swaminathan, 1998).

An intriguing question then becomes: How do population-level mutualism and competition operate in such settings with heterogeneous populations characterized by complex organizational forms? In addition, how can such settings be approached in an analytical manner for more detailed scrutinization? The next section sketches a systems approach to capture such form complexity and thus the related population heterogeneity.

2.6 A Systems Approach to Complex Forms

How is the complexity of an organizational form reflected in the domain of real organizational populations? What kind of an analytical approach should be chosen to study the processes of density dependent entry in heterogeneous populations characterized by complex organizational forms? In general, the analytical direction advanced here takes an explicit systems approach to meaningfully capture the effects of the population heterogeneity caused by complexity in organizational forms. The systems approach builds on the straightforward conceptual idea that there is a main unit and a number of hierarchically nested sub-units that are integral parts of the main unit. In the spatial context, the main unit would be e.g. a national population, in which case the hierarchically nested sub-units would then be the sub-populations at e.g. the county or city level. In the context of organizational forms, the main unit would be a main form such as biotechnology firms, and the sub-units would be the nested sub-forms such as biopharmaceutical firms and bioenergy firms.

Classic work in both human ecology (Hawley, 1950) and organizational ecology (Hannan *et al.*, 1977) have stressed the systemic nature of social structures, and the isomorphism (Hawley, 1968) between the diversity of organizational forms and the diversity of environments. Organizational phenomena and evolutionary processes can be studied at various levels of analysis, ranging from individuals through intraorganizational units, organizations, and organizational populations to organizational communities (Amburgey *et al.*, 1996; Hannan *et al.*, 1977). These levels form social systems that have hierarchical structures with nested levels and related, interdependent sub-units.

A number of earlier ecological studies have applied a systems approach to understand the microstructures organizational populations and thus account for population heterogeneity (e.g. Barnett, 1990; Barnett *et al.*, 1987; Cattani *et al.*, 2003; Greve, 2002a; Hannan, 1997; Hannan *et al.*, 1995c; Lomi, 1995a, 2000; Swaminathan *et al.*, 1991a; Wezel, 2005). However, most of these studies have set their focus on the geographical context, studying the effects related to the geographical clustering of sub-populations under a single main population. For example, Greve (2002a) has studied density-dependent entry in the Tokyo banking industry by decomposing the population into 20 sub-populations according to the wards and counties within Tokyo.

It is argued here that a similar systems approach can also be applied in the domain of organizational forms (cf. McKendrick *et al.*, 2001). This approach builds strongly on the identity based definition of the organizational form, as well as the concept of form complexity. The simple main idea is to analyze complex organizational forms as bounded systems of simpler sub-forms with closely related sub-identities. Such sub-forms are not only associated as integral parts of the main form, but also hold conspicuous own identities, thus making them different from each other. By definition, this heterogeneity and underlying hierarchical structure are reflected to empirical populations of organizations.

The conceptual starting point lies in identities and audiences. Organizational identities are often hierarchically nested, comprising of sub-identities related to each other (cf. Carroll *et al.*, 2000a: 69). The relationships between the sub-forms and the main form are systemic, and thus they form together a system of identities. Thus, complex organizational forms – as collective identities – may also have nested sub-forms with related identities (Carroll *et al.*, 2000a: 74; Ruef, 2000). This resembles in many ways the geographical clustering of populations and sub-populations.

Recall that the complexity of an organizational form stems from the heterogeneity of the codes associated to the form's collective external identity. Complexity is thus a function of (i) the number of relevant audiences and (ii) the heterogeneity of the codes that the different audiences associate to the common collective identity. For example, the member organizations of a complex organizational form might serve a multitude of different product and output markets (such as in biotechnology), thus being relevant to several different groups of target customers and stakeholders with significantly different material and social demands. Similarly, the activities, structures and operational modes of the individual organizations within a form may require multiple types of resources as inputs, e.g. employees with specialized skills. This further increases the diversity of relevant audiences.

In such settings, the different audiences may associate differentiated sets of codes to the common collective identity of the organizations. This leads to the clustering and differentiation of sub-identities in accordance with the different audiences. However, since the different audiences collectively associate the organizations to the same general identity, the codes imposed by different audiences are at least partly overlapping. Some of the codes are common to all of the associated organizational types or sub-identities (e.g. a common technology base), while others may differ (e.g. properties of end products or other outputs). Those codes that are universal across different audiences link the complex main identity and its constituent sub-identities together. Different audiences may also weight the associated identity codes differently, thus adding to the differentiation of the sub-identities.

How this clustering of identities is reflected to organizational forms? By definition, organizational forms are sociologically real categories with collective identities that are externally enforced by audiences through related identity codes. Thus, a complex organizational form has a complex collective identity. Consequently, the existence of distinct sub-identities leads to the formation of conspicuous sub-forms that are hierarchically nested under the main form. The sub-forms hold systemic relationships to the main form and the other sub-forms through the underlying system of identities.

Recall that audiences have control over material and symbolic resources for the organizations associated to a collective identity i.e. organizational form. Thus audiences are able to affect the success and failure of organizations by first screening and validating them as members and subsequently applying varying levels of valuations to the organizations. The valuations are based on the organizations' perceived conformity to the codes that the audiences except based on the collective identity they associate to the form. Thus audiences have the power to force (i.e. select) organizations to conform to specific sets of codes. (Hsu *et al.*, 2005)

This is the process by which organizations and organizational properties tend to get 'clustered' under salient organizational sub-forms that follow the identity 'maps' enforced by powerful audiences. Usually end-customers or other output-driven stakeholders represent the most powerful audiences. This is implicitly indicated by the fact that extant ecological studies have largely focused on product-market driven organizational forms. Indeed, without buyers (i.e. demand) the valuations and thus survival chances of modern for-profit organizations are severely constrained.

In the case of biotechnology, several hierarchically nested sub-identities or sub-forms has been detected under the complex main form. These sub-forms tend to more readily center around specific product or service markets, exemplified by the biopharmaceuticals, diagnostics or agrobiotech sectors. Thus the organizational forms (i.e. collective identities) of these sub-categories are clearly simpler than that of the main biotechnology form. Yet, most audiences associate these sub-forms also as integral parts of the main form (cf. Baum *et al.*, 2000; Liebeskind *et al.*, 1996; Powell *et al.*, 1996; Stuart *et al.*, 1999)

The systemic structure of an organizational form can be considered to be very strong, if explicit labels get naturally created for the individual sub-forms. These labels help to distinguish the forms from others, underlines the homogeneity of the members (and the implicitly identity codes), fosters related communication and, most importantly, helps audiences to simplify and better understand the underlying complexity of the main form. As described above, several such natural labels have emerged in biotechnology.

The hierarchical structure described above represents a relatively elementary system of forms. Going beyond the simplest case, the systems approach allows for the nesting of several additional layers. McKendrick and Carroll (2001) have also noted that such hierarchical systems can take several different structures, for example "semi-lattices", "trees", or "diamonds" (McKendrick *et al.*, 2001). Consider again the biotechnology example. The labels white, green, red, and blue biotechnology capture an intermediate level that clusters some of the individual sub-forms (biopharmaceuticals, diagnostics, etc.), but are still nested under the main biotechnology form. Interestingly, in a related vein, students of organizational taxonomy have even proposed that organizational forms could be classified into universal family trees based on an organizational genetics approach that traces organizational routines and competencies ("comps") in a way that resembles the role of genes in determining biological classifications of species (McKelvey, 1982; McKelvey *et al.*, 1983).

Now turn to populations. By definition, populations are spatial-temporal, empirical instantiations of organizational forms (Carroll *et al.*, 2000a: 59). Thus, the complexity of an organizational form gets reflected to populations and becomes visible through heterogeneity of the member organizations. With a similar logic, the systemic structure of organizational sub-forms will also be reflected in real organizational populations. The population related to the main form comprises of a relatively heterogeneous set of organizations that are clustered into sub-populations that correspond to the sub-forms. Again, these sub-populations are hierarchically nested under the main population, and the organizations belonging to a sub-population also form a part of the main population. There is also the possibility that spaces are left under the main form that do not belong to any clear sub-form. Empirically this would mean that there may be organizations that belong to the main population but not to any of the sub-populations. However, it should be noted that such sub-populations are not linked to any specific geographical clustering of the related organizations.

By decomposing a heterogeneous main population into its constituent simpler sub-populations in terms of the underlying structure of organizational forms, testable hypotheses may be drawn regarding density-dependent entry in such a heterogeneous population, as a bounded system of sub-populations. As McKendrick et al (2001) point out, several ecological mechanisms can be identified that operate between the sub-forms of such a system, and thus affect the structure and change of the whole system. Additionally, in a nested system of forms, organizational sub-forms may gain advantage from their systemic position because of taken-for-grantedness of the main form, protective action by the entities under larger system, ease of resource mobilization within the system, ease of interaction to organizations outside the system because of existing routines (McKendrick *et al.*, 2001).

In a related vein, research in community ecology has concentrated on studying broader communities of organizations, i.e. the dynamics between separate populations or populations of populations (Astley, 1985). In such settings a number of populations occupy non-overlapping niches but hold symbiotic interdependencies on each other (Aldrich, 1999: ch. 11; Hawley, 1950: 40-41). A typical symbiotic setting is a case where a population of producers holds vital and supporting dependence relationships to both the population(s) of supplier organizations as well as to the population(s) of customer organizations (Hannan *et al.*, 1995a: 30). Taking a clearly broader view beyond individual populations, community ecology focuses on organizational evolution "in the context of a concrete system of interrelationships between organizational suppliers, consumers, regulators, and intermediaries operating in an institutional area" (Ruef, 2000).

2.7 Density Dependence

Density dependence (Hannan, 1986) is one of the most central theories to explain organizational entry within the field of organizational ecology (cf. Baum, 1996; Carroll *et al.*, 2000a: Ch. 10; Wezel, 2005). The simple core idea is that there is a two-step process by which *density* – i.e. the number of organizations within a population – is related to the *entry rate* of new organizations to the population. In the first step, the level of density has an effect on two important processes of population dynamics, *legitimation* and *competition*. A rise in density increases legitimation, i.e. the general social acceptance of the underlying organizational form (DiMaggio *et al.*, 1983; Meyer *et al.*, 1977). As the levels of density further increase, competition for scarce resources from the environment also starts to get amplified (Hannan, 1986; Hannan *et al.*, 1992: 26-30). According to the theory, legitimation increases with density at a *decreasing* rate, whereas competition increases at an *increasing* rate (Carroll *et al.*, 2000a: 223-226). Therefore, the legitimation effect is strongest when a population has only a small number of organizations, whereas competition becomes salient for more dense populations[5].

In the second step, legitimation and competition again have counterbalancing effects on the entry of new organizations. In simple terms, legitimation increases the rate of entry and competition has exactly the opposite effect. The combination of the above two effects produces a *nonmonotonic* relationship between density and entry rate with the shape of an inverted U. Ignoring the process by which organizations exit from populations, this basic relationship generates an evolutionary trajectory of population density that has the shape of a stretched S and ends up with a steady state density in the time domain[6]. The core density-dependence argument was first proposed by Hannan in his seminal work (1986), and has since served as the baseline for the more recent and extended formulations of density dependent entry. Excellent reviews of the basic density-dependence argument and its recent developments and critiques can be found in existing literature (e.g. Carroll *et al.*, 2000a, ch. 10).

The basic density-dependence theory has received a substantial amount of empirical validation under a plethora of empirical contexts. A majority of these studies provide strong support for the predictions of the basic model (Baum, 1996; Carroll *et al.*, 2000a: 218; Singh *et al.*, 1990). Excellent reviews of empirical studies of density-dependence can be found elsewhere (e.g. Baum, 1996; Carroll *et al.*, 2000a: 218-219; Cattani *et al.*, 2003; Greve, 2002a; Wezel, 2005).

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[5] Usually, this also corresponds to young and mature populations, respectively. However, it must be stressed that density is here the key independent variable to explain legitimation and competition, not the passage of time.

[6] To comprehensively explain the development of population density in the time domain, one would also need to incorporate a detailed account of the exit processes of organizations from the population. A substantial body of related ecological research has indeed studied the density dependence of organizational *mortality* (cf. Carroll *et al.*, 2000: Ch. 10). However, because the aim here is to explain organizational *entry* in terms of density, the theory of density dependent exit is not relevant and is excluded on purpose.

However, many studies have found the basic model too inaccurate and have built several extensions and amendments on the basic density dependence theory - to increase the precision of the predictions, and to investigate density-dependent processes in special cases. (cf. Baum, 1996; Carroll *et al.*, 2000a: Ch. 10-11). In particular, several studies have identified the basic assumption of homogeneous populations as too simplistic and have proposed new models to account for e.g. the spatial (i.e. geographical) heterogeneity of populations (Carroll *et al.*, 1991; Cattani *et al.*, 2003; Greve, 2002a; Hannan, 1997; Hannan *et al.*, 1995c; Lomi, 1995b, 2000; Sorenson *et al.*, 2000; Swaminathan *et al.*, 1991b; Wezel, 2005).

Other extensions include density delay (Carroll *et al.*, 1989a: 31-33; Hannan *et al.*, 1992) mass dependence (Barnett *et al.*, 1990), institutional embeddedness & relational density (Baum *et al.*, 1992b), temporal heterogeneity and interactions of density and population age (Baum, 1995; Cattani *et al.*, 2003; Hannan, 1997; Wezel, 2005), interactions of size and density (Barron, 1999), effects on growth rate (Barron *et al.*, 1994), as well as weighted density models including localized competition (Baum *et al.*, 1992a), red queen (Barnett *et al.*, 1996), and niche overlap (Baum *et al.*, 1994a). The most recent additions include fuzzy density and revised models of legitimation (Bogaert *et al.*, 2006; Hannan *et al.*, 2007). Some the extensions have received mixed empirical results, such as the density delay argument (cf. Hannan, 1997).

The following section will review and formally elaborate the basic density dependence argument. The subsequent sections derive arguments and hypotheses to understand density dependent processes of organizational entry for heterogeneous populations characterized by complex organizational forms.

2.7.1 Density-Dependent Legitimation

Legitimation generally refers to institutional processes by which an organizational form gains social acceptance and recognition (DiMaggio *et al.*, 1983; Meyer *et al.*, 1977). The legitimation process conveys several advantages to both entrants and the existing organizations within a population and thus generally improves their viability (Hannan, 1986).

The primary interest in density dependence is in a specific type of legitimation called *constitutive legitimation* (Carroll *et al.*, 2000a; Dobrev *et al.*, 2001) or sometimes also cognitive legitimation (e.g. Aldrich *et al.*, 1994). Constitutive legitimation refers to the institutional process by which an organizational form becomes known to the general public and other relevant audiences. Thus the form attains a *taken-for-granted* position whereby it is generally seen as the natural way of organizing a specific type of collective action (Aldrich *et al.*, 1994; Dobrev, 2001; Hannan, 1986; Meyer *et al.*, 1977). Existing literature has exemplified this process e.g. through the case of the automobile industry (Hannan *et al.*, 1995c). Accordingly, there is currently a well known and commonly accepted, "natural" way in which automobile producers operate their business – and are expected to do so. Thus the underlying organizational form has gained a fair amount of constitutive legitimation.

A number of other types of legitimation have also been theorized. *Coercive isomorphism* (DiMaggio *et al.*, 1983) refers to a process of institutionalization where organizations gain legitimation by conforming to generally accepted rules. In *sociopolitical legitimation*, socially powerful stakeholders, such as the general public, opinion leaders, government officials and the like, accept an organizational form as appropriate and legitimate (Aldrich *et al.*, 1994; Dobrev, 2001). However, because density dependence theory seeks to explain the legitimizing effect of increasing density, the above forms of legitimation are only of marginal interest (cf. Hannan *et al.*, 1992: pp. 33-37).

Refer back to the first step of the basic density-dependent explanation. According to the basic argument, there is a relationship between population density and constitutive legitimation. Given the taken-for-grantedness explanation of constitutive legitimation, the main argument is that the legitimation rises at a decreasing rate as the density of the population increases. Moreover, the legitimation approaches a ceiling at high levels of density (Carroll *et al.*, 2000a: 224; Hannan, 1986).

On a more concrete level, this legitimizing process can be explained as follows. Initially, when the first organizations enter a population, many relevant audiences are not familiar with the new organizational form and will be skeptical to make any commitments towards the early entrants as suppliers, customers, or other stakeholders. Thus it is difficult for the early entrants to mobilize resources, secure funds, initiate operations and close first sales deals. However, as more organizations appear that represent the same organizational form, the different stakeholders will gradually become familiar with and learn more about the new type of organizational activity. The addition of still more organizations boosts the spreading of information regarding the new form. Thus, the constitutive legitimation of the form increases rapidly.

However, when the population already has many members and the form is well legitimized, the entry of additional organizations will have little effect on the general constitutive legitimation of the form. Above a certain level of density, the addition of new entrants has no effect of legitimation any more. Thus legitimation increases with density at a decreasing rate and approaches a ceiling. In formal terms,

$$L_t \propto \min[\ \upsilon(N_t),\ \xi\ ], \qquad \upsilon' > 0,\ 0 \leq \xi < \infty, \qquad [1]$$

where L_t indicates constitutive legitimation, υ is a positive function of density N_t and ξ represents the ceiling level of legitimation.

The second step in the density-dependent process involves relating legitimation to organizational entry rates. Legitimation generally conveys several advantages to the organizations that represent a specific form. As constitutive legitimation rises, organizations find it easier to mobilize resources such as skilled labor. Additionally, securing funding and increasing sales become easier as financiers and customers get educated on the operation and offerings of the organizational form in question. As the organizational form becomes taken-for-granted to the general public and key stakeholders, it will generally be easier and more advantageous for organizations to enter the population (cf. Carroll *et al.*, 2000a: 224; Hannan, 1986). Thus there is a positive relationship between legitimation and organizational entry rate. In formal terms,

$$\lambda \propto L \qquad [2]$$

Where λ represents the entry rate.

2.7.2 Density-Dependent Competition

Turning to competition, in many branches of the social and management sciences the term *competition* is generally applied in referring to observable and particularistic competitive relationships between two or more organizations. Originating, among others, from military strategy, such conceptions of competitive interaction are characterized by dyadic processes such as rivalry, competitive action, battles and conflict. However, in density-dependence, competition has a special meaning that reflects (i) organizational ecology's special view of organization-environment relationships in general, as well as (ii) the aim of density-dependence to relate the level of competition with population density.

The ecological approach to competition aims to capture indirect competitive interaction that takes place at the level of the whole population and cannot be traced between any specific pair of organizations. Such ecological competition has often been termed *diffuse competition* (Barnett *et al.*, 1987; Hannan, 1986, 1997). In diffuse competition the focus is largely on how a population of organizations indirectly competes for the resources from the environment (Hannan *et al.*, 1992: 26-30).

Following the general ecological conception of the environment, all of the organizations belonging to a population are more or less dependent on the same set of key resources from the environment, called a niche (Hannan *et al.*, 1977). Such key resources can be, for example, demand for products and services, skills and labor, funding, or purely raw materials. Moreover, such niches have natural limits on the availability of the resources called the carrying capacity (Hannan *et al.*, 1992: 29). For example, there usually is a natural limit for the demand of a specific type of product, like automobiles.

For an emerging population, a new niche or combination of available resources has usually opened up from the environment. It generally takes time for a niche to be populated with organizations representing a new, related type of organizational form. Thus, when density is small, the indirect competition for the resources is also relatively small, because the abundance of the resources from the environment is able to more than satisfy the needs of the few members of the population.

A good example of this is the emergence of the technology and markets for modern wireless telecommunication in the early 1990s. With the advent of the GSM (Europe) and TDMA (US) wireless telecommunications standards as well as compact radio and battery technology, the use of cellular phones quickly became a lucrative alternative to fixed-line phones for consumers and organizations all over the world. This rapidly opened up huge markets for cellular phones and related industries such as wireless network terminals. Thus, in the early years of the industry, a substantial abundance of resources was available in the niche – demand for phones and networks, different exploitable technologies, and the like. A number of early entrants such as Nokia (Finland) and Motorola (US) were first able to grow substantially and relatively independently, exploiting the expanding worldwide niche of resources that had gradually but quickly opened up. Later, though, competition within the industry has become rather strong as many players have entered and started to seize the opportunity.

Indeed, for more densely populated environments, the diffuse competition for resources strengthens as the available resource spaces gradually get tapped by the organizations within the population (Hannan, 1986; Hannan *et al.*, 1992: 26-30). Fewer resources are available for new entrants and, on the other hand, the entry of new organizations hits harder the existing organizations within the population, because some entrants may be able to force the existing organizations to give up some of their resource space. Ultimately, as the carrying capacity of the environment is almost fully exploited, competition starts to get very strong. This has a strong effect on the viability of existing organizations and potentially entering ventures.

Returning to the first phase of the density-dependent process and following the above logic, the argument is that the strength of competition increases with population density at an increasing rate (Hannan, 1986). Indeed, as Hannan & Carroll (1992) point out, as the number of organizations increases linearly, the number of potential competitive relationships increases geometrically. Thus, in formal terms,

$$C_t \propto \varphi(N_t), \qquad \varphi' > 0,\ \varphi'' > 0. \qquad [3]$$

where C_t is the level of competition, φ is a positive function of density N_t.

In the second step of the density-dependent process, the level of competition affects the entry of new organizations. As the abundance of resources from the environment decreases and the number of potential competitors increase, the potential gains for entering the population decreases. In other words, increasing competition has a negative effect on the entry rate of new organizations to the population. An excellent example of such highly competitive industries is the worldwide paper industry, where the entry of new players is virtually impossible. This is because the existing players consume and fiercely compete for all of the available resources from the environment – a resource niche which might even start shrinking as electronic communication gradually substitutes the demand for paper in the long run.

Thus, in formal terms,

$$\lambda \propto \frac{1}{C}. \qquad [4]$$

2.7.3 Effects Combined: How Density is Related to Organizational Entry

Putting the pieces together and combining the effects of [1] through [4] yields the general density-dependence model to explain organizational entry through population density. According to the model, as density increases linearly, the rate of entry of organizations to the population first rises, then reaches a peak and finally starts to decline back towards zero. Thus the implication is that density and entry rate should have a nonmonotonic relationship of the shape of an inverted U (Carroll *et al.*, 2000a: 228; Hannan, 1986; Hannan *et al.*, 1992: 44). In formal terms,

$$\lambda(t) \propto \frac{L_t}{C_t},$$

or

$$\lambda(t) = \kappa_\lambda(t) \frac{\min(\upsilon(N_t), \xi)}{\varphi(N_t)}, \qquad [5]$$

and

$$\lambda(t)' \equiv \frac{d\lambda(t)}{dN_t} \quad \begin{cases} > 0 & if \quad N_t < N_t^* \\ < 0 & if \quad N_t > N_t^* \end{cases}, \qquad [6]$$

where N_t^* denotes the turning-point density at which the relationship changes from positive to negative, and $\kappa_\lambda(t)$ is a function that brings together the effects of all other relevant conditions at time *t*.

Three important issues should be highlighted at this point. First, it is obvious that there is also a simple reverse link between entry rate and density. The more organizations enter in one period, the higher the density becomes in the next period. In particular, if measured on the annual level, the previous year's entry rate has a clear feedback loop to the focal year's density. However, this effect is systematic by its nature, and can be easily controlled in empirical models.

Second, as already underscored earlier, historical time *t* is not an independent variable in the basic density-dependence model although expressing the models in terms of time-varying variables has become customary in more recent formulations. That is, the key mechanism in explaining changes in legitimation and competition and thus organizational entry is not the passage of time but changes in population density (cf. Carroll *et al.*, 1989c; Carroll *et al.*, 2000a: 213; Hannan *et al.*, 1992: ch. 1).

Third, following from the above, the basic model assumes what is called *strict reversibility* (Dobrev, 2001; Hannan, 1997; Hannan *et al.*, 1992: 47-48). Because legitimation and competition are treated as timeless (i.e. dependent only on the level of density, not time), the model allows the reversal of the competitive and legitimation effects. That is, should density start falling, the basic model would first assume decreasing competition and then also decreasing levels of legitimation (Hannan, 1997). Common sense and empirical research results suggest that this is unlikely in most cases. Thus this theoretical anomaly has received considerable attention (cf. Hannan, 1997).

2.8 Critique

The domain of organizational ecology as well as the density dependence theory have received several critical notes with both endogenous and exogenous flavor. One of the earliest critiques relates to the neglect of powerful organizations (Perrow, 1986). Indeed, the standard density variable treats the competitive and institutional effects of all organizations as equal. This might become an issue for industries with a few large organizations and several small ones (Barnett *et al.*, 1990).

Second, the approach of combining two important lines of organizational inquiry – the institutional perspective (legitimation) and the ecological perspective (competition) –

has received some general level feedback that has been both positive (Zucker, 1989) and critical (Baum *et al.*, 1995b; Zucker, 1989). The main argument of this critique is that the two perspectives generally come from different intellectual traditions, which might make their integration problematic.

The third line of critique questions whether the mechanisms of constitutive legitimation and diffuse competition are able to sufficiently explain density-dependent organizational entry. It has been argued that other types of legitimation – mainly sociopolitical legitimation – may also have effects on entry, and that such legitimation may not have been appropriately accounted for in the density dependence models (Baum *et al.*, 1995b; Zucker, 1989). In a related vein, it has also been argued that effects of organization level legitimation should be separated from population level legitimation (Amburgey *et al.*, 1996). Indeed, victorious organizations may have disproportionate legitimation effects and thus affect entry in the population level. It has also been questioned whether the approach of concentrating only on diffuse competition is able to capture well enough the relevant competitive processes affecting entry and exit (Baum *et al.*, 1992a; Baum *et al.*, 1994b).

A fourth issue identified by the critique concerns the validity of the approach of measuring legitimation and competition indirectly through density (Baum *et al.*, 1995b; Zucker, 1989). Researchers have questioned whether the plain number of organizations within a population is able to indirectly capture well enough the effects of constitutive or taken-for-granted legitimation (Zucker, 1989). A similar argument has also been presented regarding the measurement of diffuse competition, combined with calls for more accurate and more direct approaches to measuring competitive processes (Baum *et al.*, 1992a; Baum *et al.*, 1994b).

Fifth, a general level critique has been presented towards the density variable itself. More specifically, researchers have debated whether density is a relevant construct in explaining organizational entry (and mortality, for that matter) as well as the evolution of organizational populations in the first place. Researchers have proposed that other factors such as time (Hannan, 1997) and mass, i.e. the sum of the sizes of all organizations in a population (Barnett *et al.*, 1990) should be integrated to the analysis. On the other hand, it has also been suggested that density might be a proxy also for processes other than legitimation and competition. Density could also be related to the growth of organizational knowledge and opportunities for nascent entrepreneurs, as well as the growth of underlying social networks, both affecting entry (Aldrich, 1999: 273-274). Finally, some critics have also noted that founding studies account only for successful founding attempts (Aldrich *et al.*, 1993; Amburgey *et al.*, 1996; Delacroix *et al.*, 1983), and the process of legitimation may be an issue only for young populations (Delacroix *et al.*, 1989; Zucker, 1989).

The above critiques have provoked detailed responses and healthy discussion among the field (see e.g. Carroll *et al.*, 1989c, 2000a: 229-230; Hannan, 1997; Hannan *et al.*, 1992: 37-39, 1995b). First, the issue related to powerful organizations has become obsolete as researchers have investigated size-dependence (Wholey *et al.*, 1992) and size-based segmentation of organizational populations (Amburgey *et al.*, 1994). Some studies have also substituted density with population mass as the key dependent variable (Barnett *et al.*, 1990; Baum *et al.*, 1992a; Delacroix *et al.*, 1989).

Second, the integration of the institutional and ecological perspectives is advocated for the sake of better understanding the processes governing population dynamics (Hannan, 1986). In fact, in defining the concept of constitutive legitimation, ecologists have noted *post hoc* that the word *institutionalization* would have been "strategically" a more appropriate choice than *legitimation* because it does not have the connotation of approval or endorsement and thus more purely reflects the taken-for-granted nature of the process (Hannan, 1997). Some of the critique has generally seen the integration of different perspectives as legitimate, as long as methodological contradictions do not pose a problem (Zucker, 1989).

Third, it has been stressed that population density has the most salient effect on the taken-for-granted type of constitutive legitimation. However, the important role of other types of legitimation has also been acknowledged. Moreover, in line with the arguments of some of the critics (Baum *et al.*, 1995b), ecologists have pointed out that sociopolitical legitimation is more tied to legislative and other specific events than the continuous measure of population density. However, a majority of the empirical works on density dependence have explicitly accounted for such institutional events through extensive analysis of the exogenous period effects that mark the major changes in the institutional environment (Hannan *et al.*, 1995b).

More generally, ecologists have stressed at several points that the generalizability of the density variable across long time periods and across various industries is an advantage of the analytical approach that more than justifies the possible sacrifices in measurement accuracy and context specificity (Carroll *et al.*, 1989c; Hannan, 1997; Hannan *et al.*, 1992: 38, 1995b). Moreover, empirical research has several times demonstrated that there is a significant effect between density and the entry and other vital rates of organizational populations and that such effects are more significant than changes in the exogenous environmental aspects (Carroll *et al.*, 2000a: 230, 240; Hannan, 1997).

Fourth, ecologists generally agree on the need to have more direct and accurate measures of legitimation and competition but, at the same time, building on the above position, argue for methods that are generalizable, cost-effective, and realistic in terms of research efforts needed (Carroll *et al.*, 2000a: 230). As Hannan (1997) notes, "both legitimation and competition are hard to [directly] measure systematically over the full histories of organizational populations". Thus, "the theory abstracts from the many conditions affecting vital rates and concentrates on *density*". Arguably, focusing on the simple observable of population density provides consistency to the analysis over long periods of time and across various industrial settings.

3 Hypotheses

This section formulates testable hypotheses regarding the density-dependent processes of organizational entry in heterogeneous populations characterized by complex organizational forms. The formulations begin by first ignoring the underlying systemic structure of the heterogeneous population and proposing hypotheses based on the classic single-population density dependence theory (Theme 1). Next, the systems approach sketched in the previous sections is incorporated, and the analysis is focused on the simple case where a number of individual sub-populations are directly nested under the main population (Theme 2). The third formulation increases detail by assuming an intermediate level of aggregation between the main population and the individual sub-populations. Such intermediate levels will be nominated as "clusters" of sub-populations" (Theme 3). All of the three formulations aim to capture how strongly the processes of legitimation and competition affect entry and, more importantly, from which parts of the system do these effects originate.

3.1 Theme 1: Classic Single-Population Density Dependence

The classic density-dependence argument (Hannan, 1986) suggests that the density-dependent effects of legitimation and competition should apply to any ecological population of organizations. It proposes that population density has *both* a legitimizing and competitive effect on the entry rate within the *same* population.

As discussed earlier, for heterogeneous populations characterized by complex organizational forms, it is possible to define and observe individual populations at different levels of aggregation. Recall that under the systems approach to organizational forms, it was assumed that a complex main form comprises of hierarchically nested, simpler sub-forms. Based on the identity-based approach to organizational forms (Hsu *et al.*, 2005; Polos *et al.*, 2002), both the main form and the underlying nested sub-forms can be considered as appropriate bases for defining real ecological populations. For example, the main form 'all biotechnology firms' and one of its sub-forms, 'biopharmaceutical firms', could both be used as bases for ecological analysis of population dynamics individually, ignoring the possible effects of the underlying system of populations.

Based on the above logic, the classic density-dependence theory should then apply on both levels – within the main population and within each of the individual sub-populations. This proposition can easily be backed up by the standard arguments behind density dependence. Consider the case of biotechnology. As any firms rooted in biotechnology start to enter the field, key stakeholders such as investors and technological experts become familiar with the form. Potential entrepreneurs get interested in the upside potential underlying the future products and services enabled by the technological base. Audiences generally start to view such firms as legitimate and lucrative forms of organizing economic activity. Thus legitimation boosts entry to the field in general. However, as the number of firms grows, resources such as finance, talent and demand for products and services start get fully exploited by the existing group of firms. Thus competitive forces set in to hinder the entry of new organizations.

A similar argumentation can be cast to any of the underlying sub-forms of biotechnology, such as biopharmaceuticals or agrobiotech firms or firms specialized in biological enzyme production. Of course, here the arguments are somewhat more precise, because one can talk about specific sets of products and demand thereof, as well as more specific audiences that hold stake and power regarding the focal sub-form.

Based on the above, the following hypotheses are presented:

> *H1a: When the systemic structure of the population is ignored, main population density has a legitimation (positive linear) and a competitive (negative squared) effect on the rate of entry of organizations to the main population.*

H1b: When the systemic structure of the population is ignored, sub-population density has a legitimation (positive linear) and a competitive (negative squared) effect on the rate of entry of organizations to the sub-populations.

The above hypotheses will be used as the baseline for the analysis, and will be refined with additional hypotheses formulated in the following sections.

3.2 Theme 2: Density Dependence in a Simple Hierarchical System

How, if at all, do these predictions differ when the systems approach is incorporated to the analysis? A natural starting point for this is to consider one of the simplest possible systemic structure: a single main form (or empirical population) with a limited number of sub-forms (populations) that are hierarchically nested directly under the main unit. Thus, besides the isolated effects within the main population and the individual sub-populations, are there density-dependent effects that operate across the different levels, hence taking into account the whole underlying structure of the complex organizational form?

The different sub-forms have a systemic relationship to a single main form and thus also to one other. Thus one would expect that the entry of organizations to the sub-populations – and the underlying density-dependent processes – do not operate in isolation from the main population and the other sub-populations. More precisely, because the individual sub-forms have a hierarchically nested relationship to the main form, does the main population (i.e. all organizations representing the main form) have density-dependent effects of legitimation or competition on the entry of organizations into individual sub-populations?

The above question relates to the underlying networks of dependence relationships between the sub-populations and the main population (cf. Lomi, 2000) as well as to the permeability of the internal boundaries of the system in terms of resources and institutions. The main proposition advanced here is that legitimation is more readily transmitted across system boundaries, whereas competition tends to be more tied to resource niches that are specific to individual sub-populations. Thus it is argued that the density of the main population has a legitimizing but not a competitive effect on the entry rates within individual sub-populations. Extant research has proposed and confirmed similar effects in the context of spatial heterogeneity, i.e. geographically clustered sub-populations (e.g. Hannan, 1997; Hannan *et al.*, 1995c).

To back up the analytical approach taken here, it is briefly noted that complex networks of interdependence relationships exist between organizations (Hannan *et al.*, 1995c; Lomi, 2000). Such interdependencies concern both the access to external resources (Carroll, 1985; Hannan *et al.*, 1977) as well as processes of institutionalization (Aldrich *et al.*, 1994; Hannan, 1986). The interdependence relationships also define the permeability of boundaries within a system, and thus how the processes of resource access and institutionalization operate across the system boundaries.

Consider first legitimation. An organizational form gaining constitutive legitimation means that the form becomes generally known, as well as accepted as the standard structure for organizing a specific type of collective action (Aldrich *et al.*, 1994; Hannan, 1986). Density has become a standard observable indicator of the legitimation of an organizational form (Carroll *et al.*, 1989c; Hannan, 1997; Hannan *et al.*, 1995c).

The legitimizing effect of the main form on a hierarchically nested sub-form depends on the legitimation of the main form itself, as well as how the sub-form is associated to the main form. According to the identity approach to organizational form, audiences associate organizations into forms (or collective identities) based on the organizations' conformity to the associated rule-like identity codes (Hsu *et al.*, 2005). By definition, the members of a sub-form are implicitly accepted also as members of the main form. In other words, conformity to the codes associated to the sub-form also guarantees conformity to the (less uniform) codes associated to the main form. Thus, from the perspective of taken-for-granted legitimation, the sub-forms are directly associated to the main form.

According to the above logic, the legitimation of the main form will have a positive effect on the legitimation of the sub-form. Indeed, when knowledge concerning the general organizational type represented by the main form spreads and it becomes generally accepted, the viability of *all* organizations representing to the main form is increased – including the nested sub-populations. It generally becomes easier for all organizations representing the general form to mobilize resources of different kinds. Additionally, potential entrants find it more advantageous to replicate the existing form and enter the organizational field. These effects naturally span the underlying sub-forms.

Thus, following the basic density-dependence argument, besides the density of the sub-form itself, the density of the main population should also positively affect the legitimation of the sub-form. Thus the density of the main form will also have a positive effect on the entry rate of organizations to a sub-population.

Consider next competition. Density-dependent diffuse competition within an organizational population is driven by the process by which organizations indirectly compete resources from their common environmental niche (Barnett *et al.*, 1990; Hannan, 1986; Hannan *et al.*, 1992; Hannan *et al.*, 1977). Key external resources to organizations include demand for their products and services, skilled labor, raw materials, facilities, financing, and so forth. Density is generally used as the standard observable measure for diffuse ecological competition (Carroll *et al.*, 1989c; Hannan, 1986; Hannan *et al.*, 1992).

By definition, the organizations within a single population are dependent on the same set of resources, i.e. they occupy the same niche in their environment (Carroll, 1985). However, the different sub-populations under a main population generally do not occupy entirely same ecological niches. For example, a complex main form may be defined by a common scientific or technological base (or some other non-product-market resource environment). The underlying simpler sub-forms may again be driven by different product-markets utilizing the common technological base. Because demand for products and services represents a key resource to organizations, the different sub-populations clearly occupy non-equal sets of resources. This is comparable to a situation where the sub-populations under a spatially distributed main population depend on different, localized sets of resources (Lomi, 1995a). The European automobile industry has been used as an example of this, as illustrated by its nationally bounded sub-populations and demand for automobiles thereof (Hannan *et al.*, 1995c).

It should be noted that the resource niches of individual sub-populations may be partially overlapping. This might be the case e.g. when different sub-populations serve different markets but share a common dependence on finance or employees with a specific type of technological expertise. However, this represents only part of the competitive space of the related organizations, and the general difference between the resource niches remains.

Because the different sub-populations underlying the main population represent a rather diverse overall set of resource niches, one really cannot say that all other organizations under the main population will exert a full-fledged competitive effect on the organizations within an individual sub-population, dependent on a specialized niche. Using the biotechnology industry as an example, consider biopharmaceutical firms on one hand and the producers of industrial enzymes on the other. The target customers and demand for products and services of these firms practically do not overlap at all. On the contrary, these two forms might even have a mutualistic relationship (Barnett *et al.*, 1987) in terms of creating products and services to the society.

In addition, there can be several resource niches under the main form with non-exhausted carrying capacities (Hannan *et al.*, 1992: 29). Thus the addition of new organizations to such sub-populations doesn't necessarily consume the resource space of the other sub-populations at all. A good example of this is the bioinformatics sector, which has emerged significantly later than many other sub-fields of biotechnology. Bioinformatics firms help other biotechnology fields in using computational methods to model and test various kinds of biological effects and processes. For example, pharmaceutical firms increasingly use bioinformatics methods to intelligently design and model the effects of new drug molecules – instead of the more traditional methods of high throughput screening of massive amounts of potentially useful molecules. Bioinformatics was launched by advances in computer and modeling technology, as well as brute computing power – representing an unexploited new niche in the resource space. Again, the entry of bioinformatics firms has probably exerted little competitive pressure to most of the other sub-populations in biotechnology.

Based on the above, it is proposed that the density of the main form does not have a direct effect on the density-dependent competition within a sub-population. Thus the density of the main form does not have a competitive effect on entry rates within sub-populations.

The combination of the above legitimation and competitive processes yields the following hypothesis:

> *H2a: When the systemic structure of the main population is taken into account, main population density has a legitimation (positive linear) but not a competitive (negative squared) effect on the rate of entry of organizations to the sub-populations.*

> *H2b: When the systemic structure of the main population is taken into account, sub-population density has a legitimation (positive linear) and a competitive (negative squared) effect on the rate of entry of organizations to the sub-populations.*

While the competitive effects on organizational entry should be mainly contained to the sub-population level, effects of density-dependent legitimation are assumed to originate from besides the focal sub-population itself, also from the main population. Given this, an intriguing question arises: how, if at all, do the legitimation effects of these two levels differ in magnitude? Where does the majority of the legitimizing power originate from?

In the geographical domain, extant research has found local density to have the greatest effect of density-dependent legitimation (Cattani *et al.*, 2003; Greve, 2002a). The simplified argument is that network ties, social interaction, information sharing, and the number of personal contacts are strongest between geographically close actors. Thus the effects of constitutive legitimation are also most prevalent at the local level (Cattani *et al.*, 2003).

However, this logic is not directly transferable to the domain of complex organizational forms where the level of social interaction and the permeability of system boundaries is not defined by physical distance. The members of a sub-population may be geographically scattered while still holding a common identity and form. Similarly, the members of a geographically agglomerated group of firms may represent several different sub-forms even though they belong to the same main form.

A somewhat different effect is proposed here for the context of complex organizational forms. It is argued that the main population density will have a stronger legitimation effect on sub-population entry than the density of the sub-populations themselves. The origins of this effect lie in several mechanisms and structural properties that are prevalent in heterogeneous populations characterized by complex organizational forms, as explained in the following.

The first mechanism lies in the use of linguistic labels. Extant research has shown how linguistic labels appear for sociologically real categories (Hsu *et al.*, 2005). The existence of such labels fosters the taken-for-granted legitimation of forms because audiences find it easier to distinguish the forms from other units in the social world, and also makes them generally more accessible (DiMaggio, 1997; Hsu *et al.*, 2005). Moreover, labels also facilitate communication related to the forms (Hsu *et al.*, 2005).

In the context of complex organizational forms, the sub-units of the system (i.e. the sub-forms and populations) hold separate, though related, collective identities and thus labels. In the case of biotechnology, this is illustrated by labels such as 'biopharmaceuticals', 'biomaterials', bioinformatics', and 'agrobiotech'. However, very often social actors simplify communications and other social interaction by replacing sub-form labels with the main form label. Thus, general communication by several audiences – general public, media, investors, and the like – very often uses the word "biotechnology" instead of the sub-form labels. A good example of this can also be found from extant biotechnology related organization and management research that has been published through mainstream outlets. Very often the word "biotechnology" is used, even though a majority of the studies concentrate to pharmaceutical or other human therapeutics firms only (see e.g. Lerner *et al.*, 2003; Oliver, 2001; Powell *et al.*, 1996). Another example is the institutionalization of general nicknames such as 'biotech' to refer to biotechnology firms in general. Such simplification and label replacing also makes the institutionalization effects of the main form label stronger relative to sub-form labels. Whenever communication and other social interaction takes place related to any of the sub-forms, very often the main form label is used, and thus the institutional effects spill over to the whole main form and thus the other nested sub-forms.

The second mechanism relates to absolute levels of density, i.e. the sheer number of firms. By definition, the density of a sub-population is restricted to a potentially much smaller scale than the density of the main population. This means that the legitimizing effect of density cannot by definition be as high for the individual sub-populations as for the main population. Combined with the increased use of the main form label in communication and interaction, it is obvious that the density of the whole main population should show stronger legitimation effects than the densities of the individual sub-populations.

Third, Aldrich and Fiol (1994) list several processes at different levels of analysis by which emerging industries gain constitutive legitimation. In their analysis, the processes that operate at higher levels of aggregation are such that they are likely to have a stronger and more profound effect on constitutive legitimation than those that take place at lower levels. At the highest level of analysis, what the authors call "institutional", a key process in promoting legitimation is "developing knowledge base by creating linkages with established educational curricula" (Aldrich *et al.*, 1994). Clearly, for technology-based complex organizational forms, such activities are most viable and salient at the level of the main form, but decrease in magnitude and impact in comparison to the individual sub-forms. Indeed, in the biotechnology example, extant research has shown that the biotechnology industry is generally characterized with strong networks to universities and academia (Powell *et al.*, 2005; Zucker *et al.*, 1998).

One step lower, at the "interindustry" level, processes for developing cognitive legitimation include promotional activities through third parties such as media, industry associations, and trade associations (Aldrich *et al.*, 1994). Again, such promotional efforts are likely to have more profound effects at the level of the main form than at lower levels. In biotechnology, for example, several powerful industry associations exist that serve as collective advocates for the whole industry. Examples include the U.S. based Biotechnology Industry Organization BIO, the European Federation of Biotechnology, and EuropaBio, the European Association for Bioindustries. None of these major associations are focused to promote a specific sub-field of biotechnology, but the field in general. Clearly, the institutionalization efforts at the levels of individual firms or sub-forms– symbolic language/behavior and developing dominant designs, respectively (Aldrich *et al.*, 1994) – are less likely to have as much impact on general cognitive legitimation as the processes at the level of the main form.

Finally, as described above, the legitimation processes operating at the system of organizational forms does not feature similar proximity-based local proliferation of network ties and communications relationships as in the geographical context. This makes the other processes described above more salient in the context of organizational forms, and thus shows a lower legitimizing power of local or sub-unit density vis-à-vis the geographical context.

Thus the following hypothesis can be formulated:

> *H2c: The effect of density-dependent legitimation on sub-population entry is stronger for main population density than sub-population density.*

3.3 Theme 3: Density Dependence in a Three-Level Hierarchical System

The systems approach to heterogeneous populations characterized by complex organizational forms can be taken one step further by considering an intermediate level of aggregation between the main form and the individual sub-forms. Even though being different and separately labeled, the collective identities of some sub-forms may be closer to each other than the rest. This is clearly visible in the biotechnology industry. For example, a number of sub-forms including biopharmaceuticals, diagnostics, and biomaterials together form a larger group with the common property of offering products and services to the healthcare sector. As mentioned earlier, labels such as “red biotechnology” or “healthcare biotechnology” are often used to refer to this broad category. Another such cluster of sub-forms under biotechnology is called “white biotechnology” that consists of actors focusing on industrial applications of biotechnology.

How does the introduction of the intermediate "cluster" level affect predictions of density-dependent legitimation and competition? Consider first legitimation. The earlier sections provided a detailed elaboration on how effects of density-dependent legitimation on sub-population entry originate from two levels of aggregation: the main population and the sub-populations themselves. Given the mechanisms by which the legitimation effects at the two levels unfold, it is a logical consequence that also the intermediate cluster level should have a density-dependent legitimation effect on sub-population entry. Indeed, the structural relationship of a cluster to its constituent sub-populations resembles greatly the relationship of the main population to its (directly nested) sub-populations. Of course the identities of the clustered sub-populations are closer to each other, but this should not make the legitimizing effect of the cluster density nonexistent – quite the contrary. Thus it is proposed that cluster density has a density-dependent effect of legitimation on entry rates in those sub-populations that are members of the cluster.

Turn next to competition. In the simple two-level hierarchy, competitive effects were proposed to be present only at the sub-population level. The reason for this was that ecological competition is essentially diffuse competition of resources from the environment and thus limited only among those organizations that share the same environmental niche. It was noted that for a complex main organizational form, individual sub-populations are likely to differ from each other in terms of their resource niches (most notably demand for specific types of products and services). Thus density-dependent effects of competition would be insignificant at the main population level, unless a severe resource constraint affected all member organizations equally.

To determine the competitive effects of cluster level density, the key question becomes how similar the niches of the constituent sub-populations are. Are the niches similar enough to generate competitive pressures across the sub-populations at high densities? Recall from the above discussion that the clusters are typically defined by a very broad product market category, such as 'healthcare applications' or 'industrial applications'. Thus, the sub-populations within a cluster are dependent on the same, though rather broadly defined, demand for products and services. Recall also that there are certain types of environmental resources of which *all* sub-populations are commonly dependent on. Such common resources include technological know-how, educated experts, private investors, and the like. Given the above, it is assumed that the organizations and subpopulations within clusters defined in the above terms hold similar enough resource niches to produce a cluster level density-dependent effect of competition. This competition will affect the rates of entry of organizations to the constituent sub-populations.

Thus it can be hypothesized:

> *H3a: When the systemic structure of the main population is taken into account, the density of a cluster of sub-populations has a legitimation (positive linear) and a competitive (negative squared) effect on the rate of entry of organizations to the sub-populations that are members of the cluster.*

A final point of interest is the relative strength of the legitimizing and competitive effects of the cluster level density. Are these effects likely to be stronger or weaker than those of the individual sub-population densities? As for legitimation, it was earlier proposed that main population density will have a stronger legitimizing effect than sub-population density. This effect was explained through several mechanisms, including the use of linguistic labels, the relative size of the main population, more powerful legitimizing efforts at higher levels, as well as the lack of geographical concentration of interaction relationships in the context of organizational forms. Most of these arguments can quite readily be used in proposing a similar effect strength argument for the cluster level density. Most notably, the power of numbers applies here as well, i.e. the absolute densities of clusters are, by definition, clearly higher than those of the constituent sub-populations. Thus the legitimation effects are likely to be higher. The linguistic effect is also likely to be present, as well as the collective inter-industry legitimization efforts suggested by Aldrich and Fiol (1994). Indeed, it is likely that the sub-populations belonging to a single cluster are likely to engage in collective promotional and political efforts to promote the legitimacy of their common field. Also the usage of common language as well as the creation of dominant designs are likely to occur at this level. Also the lack of geographical concentration of interaction argument applies here.

For competition, it is proposed that the effect is generally stronger for sub-population density than cluster density. This follows logically from the fact that the organizations within a sub-population are dependent on virtually the same resource niche, whereas the niches of the sub-populations within are likely to differ to a greater extent. Because ecological competition is caused by firms trying to exploit a common set of limited resources, this kind of competition is likely to be stronger within sub-populations than clusters.

Thus it is hypothesized:

> *H3b: The effect of density-dependent legitimation on sub-population entry is stronger for cluster density than sub-population density.*
>
> *H3c: The effect of density-dependent competition on sub-population entry is stronger for sub-population density than cluster density.*

4 The Modern Biotechnology Industry in Finland

It is generally acknowledged that the beginning of the era of modern biotechnology was marked by the invention of a specific technique to synthesize DNA by professors Cohen and Boyer in 1973 (McKelvey, 1996, p. 93; Oliver, 2001; Stuart *et al.*, 1999; Walker *et al.*, 1997). Other early breakthroughs in modern biotechnology were the first production of monoclonal antibodies by Millstein and Kohler in 1975 as well as the method for rapid DNA sequencing by Gilbert and Sanger in 1977 (Walker *et al.*, 1997). All of these subsequent inventions were made possible by the pioneering work by Watson and Crick in 1953 when they discovered and first described the double-helix structure of DNA (Watson *et al.*, 1953).

These developments in science and technology have lead to a proliferation of novel biotechnological products and production techniques, such as the production of insulin and other human proteins in microbes (McKelvey, 1996). Also a novel organizational form started to emerge, focusing on high R&D investment and the creation of novel products making use of the new technological advances. The modern biotechnology form started to be populated worldwide by small and innovative firms as well as entrants from the traditional biotechnology industry and other adjacent industries (cf. Aldrich, 1999: 316-317).

The following sections provide a detailed qualitative description and analysis of the Finnish modern biotechnology industry since the early 1970s. First, the historical evolution of the industry is analyzed, including a description of the population of Finnish biotechnology firms. Thereafter, the key characteristics of the institutional environment faced by the Finnish biotechnology industry are described, including an analysis of the key historical events that have shaped the evolution of the industry. The final section identifies and describes the different sub-forms and describes their evolution as integral parts of the overarching biotechnology industry.

4.1 Historical Evolution of Modern Biotechnology in Finland

In Finland, the beginning of the era of modern biotechnology is generally associated likewise to the early-mid 1970s (Ruutu, 1990)[7]. The first ten to fifteen years were marked by moderate creation of young and innovative firms (*de novo*), as well as the gradual entrance of firms from other fields (*de alio*), such as the traditional pharmaceutical industry, chemical industry, and the food and feed industries. Many of the earliest de novo entrants were diagnostics firms, including Farmos Diagnostica, Labsystems, Immuno Diagnostic, and Orion Diagnostica. Entries of de novo biopharmaceuticals started to follow, including the founding of the following firms in the 1980s: Genesit, Innofarm, Ipsat Therapies, and Jurilab. Also other sub-fields of the biotechnology industry attracted de novo entrants, such as Bioferme (food & feed), Bioscience (biomaterials; later Bionx Implants), DN Bioprocessing (bioenergy and environment), Eflab (devices), and Hortus (agrobiotech). Early de alio entrants included firms that started gradually applying modern biotechnology techniques and methods, as well as increased their R&D investments to related areas. Examples of such de alio entrants include Alko (enzymes), Leiras (pharmaceuticals), Orion (pharmaceuticals), Raisio (food & feed), and Valio (food & feed).

The twelve-year-period starting from 1989 was marked by a rapid growth of the Finnish biotechnology industry. Whereas a total of approximately one hundred entries were recorded between 1973 and 1988, the subsequent years until 2006 featured approximately 300 entries, which is almost three-fold when compared to the earlier

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[7] The definition and timing of modern biotechnology was also brought up in the interviews of six Finnish biotechnology industry experts. All of them associated the era of "modern biotechnology" to the early inventions in gene technology that are generally referred to in organizational research in biotechnology. In addition, the interviewees unanimously confirmed that the beginning of the modern biotechnology industry in Finland took place in the early to mid 1970s.

period. Despite increasing exits (138 in total, 95% of them after 1988), the total number of firms rose quite rapidly, starting from less than 100 firms in 1988 to more than 250 in 2001. However, the post-2001 era was characterized by a clear slowdown in industry growth. During the observation period 1973-2006, the highest number of firms was recorded in 2004 with altogether 269 biotechnology firms operating simultaneously in Finland. In general, a great majority of the entrants were de novo entrants. From a total of 401 entries between 1973 and 2006, only 36 were de alio entries, thus representing less than one tenth of all entries. See Figure 2 for a graphical representation of the density and entry rate of biotechnology firms.

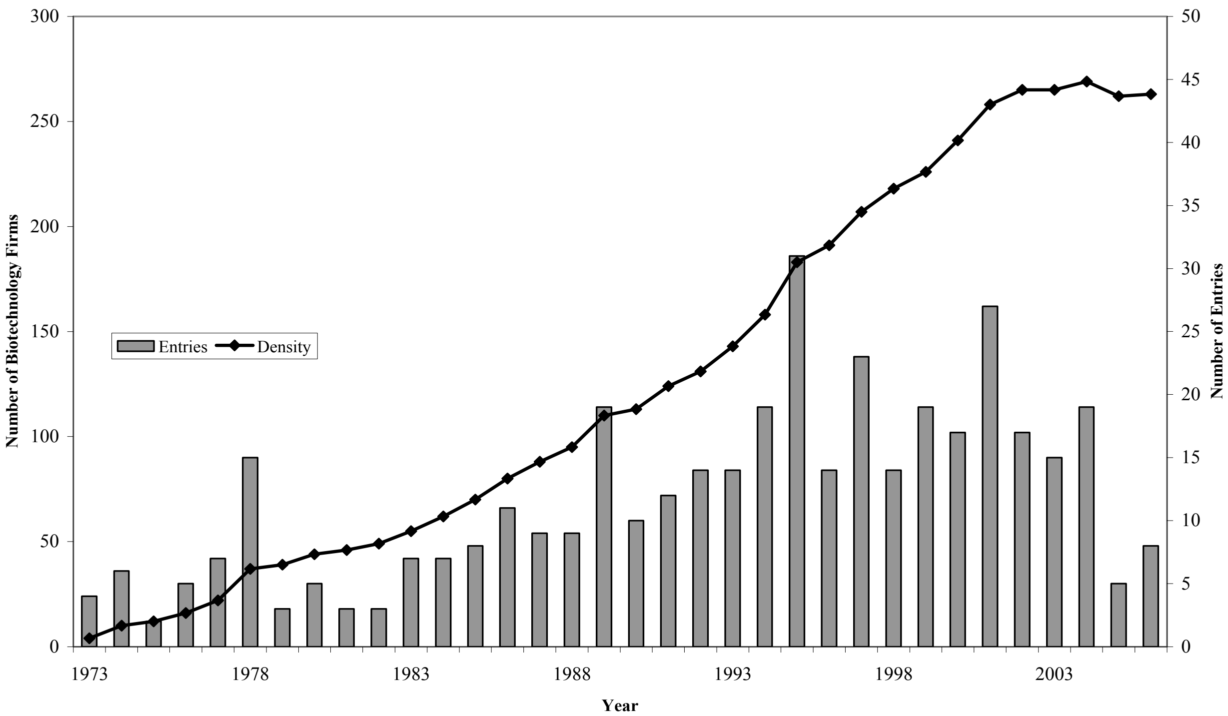

Figure 2: The Finnish Biotechnology Industry in 1973-2006 - Density & Entries

The era before modern biotechnology, starting from around 1930-40, is sometimes called “classic biotechnology” and was characterized by the production of antibiotics, amino acids, enzymes, and the like (Ruutu, 1990). During this period, Finland received its first Nobel prize which was awarded to the renowned biochemist and professor Artturi I. Virtanen for his strong research and industrial impact in the field of biochemistry, as exemplified by the AIV method for preserving fresh fodder invented in 1928 and patented in 1932, and still in use worldwide. Looking further back, the earliest use of biotechnology (though not the word "biotechnology") can be traced thousands of years earlier to the first production of products like beer (Ruutu, 1990).

4.2 The Institutional Environment of the Finnish Biotechnology Industry

During the past decade or so, the Finnish biotechnology industry has faced strong public expectations about becoming one of the industrial cornerstones of the Finnish economy – in addition to the traditionally strong paper and pulp industry and the more recently established ICT sector (Hermans *et al.*, 2006a; Schienstock *et al.*, 2001; Virolainen, 2000). However, in 2000, the total turnover of the Finnish biotechnology industry was a little less than 2 billion euros and the industry employed around 10 000 people, representing only 1.2 % of GDP and 0.2 % of total population, respectively (Academy of Finland, 2002).

Numerous interorganizational alliances (Baum *et al.*, 2000; Calabrese *et al.*, 2000; Oliver, 2001; Powell *et al.*, 2005) and strong networks to science and academia (Liebeskind *et al.*, 1996; McKelvey, 1996; Powell *et al.*, 1996) have been identified as key characteristics and success factors in the biotechnology industry. The Finnish network of industrial and scientific activity in biotechnology has strongly concentrated on six geographical areas, the Helsinki and Turku city regions being the most notable ones (Hermans *et al.*, 2006b; Höyssä *et al.*, 2004; Schienstock *et al.*, 2001). Each of these geographical clusters has been formed around a local university. These universities together host a total of 14 biotechnology related graduate schools (Schienstock *et al.*, 2001). To build bridges between industrial companies and scientific institutions, the Ministry of Education of Finland established the first national biotechnology program in 1988, with the aim of creating strong regional centers of excellence. By 2000, as the program finally ended, altogether six such centers of excellence had been established, having a significant effect on the biotechnology industry (Schienstock *et al.*, 2001).

Besides alliances and scientific networks, sufficient funding has been found to be a vital success factor in the biotechnology industry (Lerner *et al.*, 2003; Schienstock *et al.*, 2001). A major part of the funding of Finnish biotechnology has originated from public sources, with three public institutions being the most active (Schienstock *et al.*, 2001). The Finnish Innovation Fund SITRA, under the direct supervision of the Finnish Parliament, started funding biotechnology in the early 1980s (Enari, 1986). SITRA has mainly focused on the early stage equity funding of technology-based Finnish companies and ventures. In addition to SITRA, the Finnish Funding Agency for Technology and Innovation TEKES was established in 1983, and has since had an increasing national role in funding applied research and development in various fields, including biotechnology. A third major source of funding for Finnish biotechnology has been the Finnish Academy (Schienstock *et al.*, 2001). However, the funding by the Academy has been directed at scientific research, thus having a less direct effect on the industrial activities in biotechnology. Lagging behind the U.S. and most of Europe, the role of venture capital was rather insignificant in the 1980s, but started to grow in the 1990s. A peak in Finnish venture capital investments was reached in 2000 with total investments of € 397 million and € 15.5 million in biotechnology (FVCA, 2006). However, as the figures illustrate, venture capital investments in Finnish biotechnology have generally been rather scant when compared to the United States, for example.

The post-2000 period was marked by a less favorable environment for biotechnology in Finland. The growing trend of venture capital investments in the 1990s turned to a steadily declining trajectory with the advent of the new millennium (FVCA, 2006). The public discussion started to show marks of dissatisfaction regarding the relatively slow growth of the biotechnology sector – especially when compared to the ultra-fast growth of the ICT sector in the 1990s, lead by the Finnish star company Nokia. The public disappointment and decline of expectations were fueled by SITRA's post-2000 decision to substantially lower its funding of the biotechnology sector, and divest many of its biotechnology investments.

The Finnish economy has grown rather steadily since the beginning of the 1970s. During this period, the real GDP of Finland has grown to approximately 2.5-fold, as can be seen from Figure 3 below. It can also be observed that there have been two recessions within the period (defined as zero or negative GDP growth). The first recession took place in 1976-77 with two subsequent years of zero GDP growth. The second, much more severe recession took place in 1990-1993 with as high as six per cent negative GDP growth in 1991.

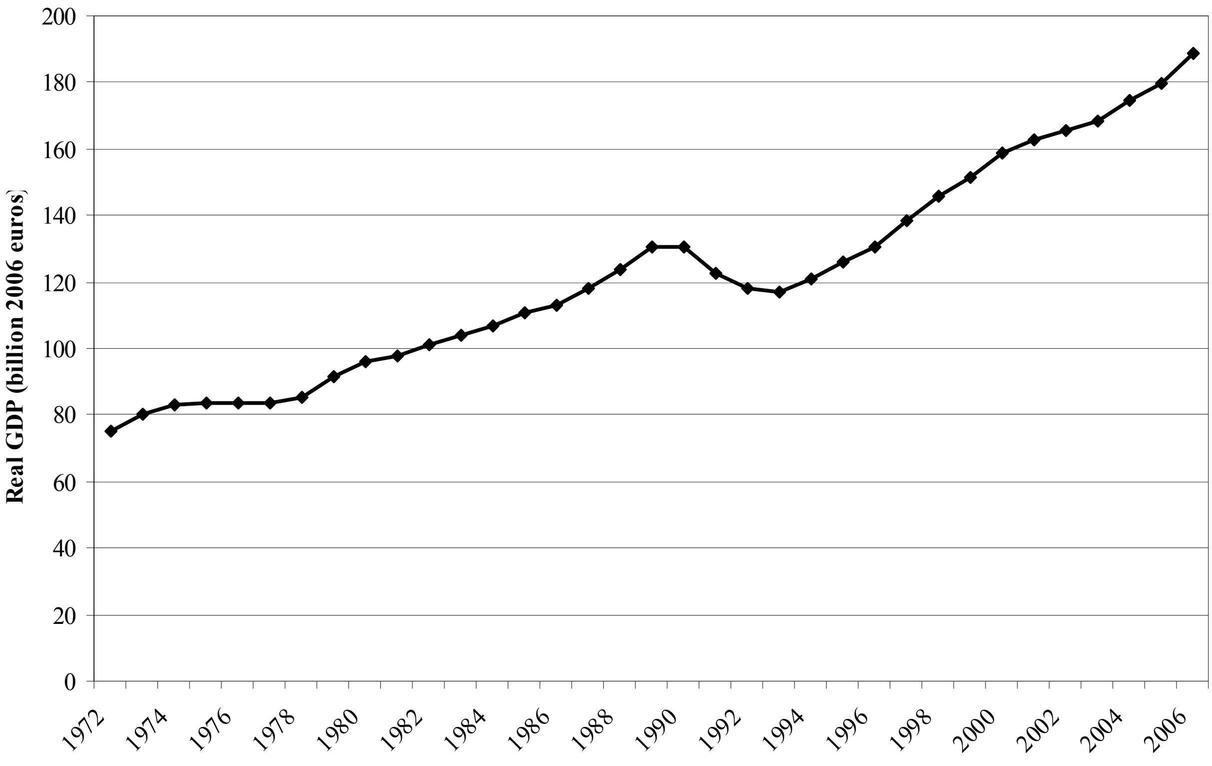

Figure 3: Real GDP of Finland 1972 - 2006[8]

Finally, a number of historical events can be identified in the institutional environment of the Finnish biotechnology industry. These events are such that they are likely to create clear discontinuities in the evolutionary trajectory of the industry. First, the years 1977-78 featured a combination of several simultaneous developments creating discontinuity. The invention of the rapid DNA sequencing method by Gilbert and Sanger in 1977 was a major technological breakthrough that had concrete impacts on the development and production of biotechnological products and services (Walker *et al.*, 1997). Additionally, recombinant human insulin was first produced in 1978 which also greatly concretized the technological possibilities of the field and increased its visibility (McKelvey, 1996). 1978 also marked the founding of a major industry organization, the European Federation of Biotechnology. An institutional event also occurred inside Finland, as the annually held biotechnology discussion and networking forum, "Biotieteiden päivät", was held for the first time in 1978. The same year, the Finnish economy also started to recover from its mid-1970s recession.

A second combination of multiple institutional events occurred ten years later, in 1988. This proved to be a year when many important public programs for developing and funding biotechnology were launched in Finland (Enari, 1988). These programs included the first major biotechnology program by TEKES (Nybergh, 1988), the national biotechnology program by the Ministry of Education (Schienstock *et al.*, 2001), the Nordic Biotechnology Programme 1988-1992 by the Nordic Council of Ministers (Viikari, 1988), and the biotechnology development program for 1988-1992 by the Finnish Academy (Enari, 1988). One can still add to the list the announcement of SITRA to fund a major center for cell research as well as the biotechnology program by Nordisk Industrifond (Enari, 1988). Besides fueling the availability of resources, these combined events probably had strong institutionalization effects on the industry

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[8] Source: The Conference Board and Groningen Growth and Development Centre, Total Economy Database, March 2007, http://www.ggdc.net.

as a whole, especially related to building sociopolitical legitimation (cf. Aldrich *et al.*, 1994; cf. Hannan *et al.*, 1995b).

Two additional institutional events occurred during the period of observation. First, a major change in the regulatory environment took place as Finland joined the European Union in 1995. Second, as discussed already above, the year 2001 marked the beginning of a period characterized by a rapid decline in the availability of funding as well as declining public attitude (Saarinen *et al.*, 2003). This year also the worldwide economy declined severely after the general overheating and over-expectation in the stock markets in 1999-2000.

4.3 Sub-Forms under Finnish Biotechnology

The Finnish biotechnology industry is characterized by numerous sub-fields and salient differences between their organizational forms (cf. Luukkonen, 2005). In particular, several distinct product-markets and/or application areas can be identified, some of which are completely non-related (e.g. bioenergy vis-à-vis biopharmaceuticals). At the same time, all relevant audiences associate the sub-forms to the main biotechnology form. This is a pattern that characterizes biotechnology industries worldwide (cf. Baum *et al.*, 2000). Historically, the "clustering" of the Finnish biotechnology has taken place mainly within pre-existing industrial sectors such as the agro-food industry, the pharmaceutical industry, as well as the wood processing and chemical pulp industry (Schienstock *et al.*, 2001). Kreiner and Schultz's (1993) description of the Danish biotechnology industry fits the Finnish case well: "In a loose sense, we may talk about a biotech community, since across all differences, all the competing classifications being applied and used, they identify themselves in certain situations and contexts as working in biotech."

Table 5 below shows the evolutionary pattern of the different sub-forms of the Finnish biotechnology industry, as reported in various industry and trade journal articles and general industry descriptions between 1979 and 2006. Interestingly, brewing was still seen as a separate field in the 1970s, but has been combined to the food sector in the latter reports. Additionally, the earliest listing did not include the food sector at all – perhaps because of the very small number of food related biotechnology actors in the 1970s.

In the early listings, most of the reported sub-forms represent traditional industrial biotechnology, while the healthcare related pharmaceutical and diagnostics sub-forms did not become visible until the 1981-82 and 1986 listings, respectively. Similarly, biomaterials got included in 1989, after the success of the early entrants such as Biocon and Bioscience in the 1980s. First bioinformatics firms, including CSC Tieteellinen Laskenta, entered early 1990s, which is again shown by the addition of the new form into the industry descriptions from 1994-95 onwards.

Table 5: The Evolution of the Sub-Forms of the Finnish Biotechnology Industry

Year	**1979**	**1981-82**	**1986**	**1989**	**1994-95**	**2001**	**2006**
Reported Sub-forms of Biotechnology	Brewing Energy Enzymes Wood processing Yeasts	Agriculture Chemicals Energy Enzymes Food Forest Pharmaceuticals	Agriculture Diagnostics Fine Chemicals Food Forest Pharmaceuticals	Agriculture Biomaterials Chemicals Diagnostics Environment Food Forest Pharmaceuticals	Bioinformatics Diagnostics Environment Enzymes Fine Chemicals Food Forest Pharmaceuticals	Agriculture Biomaterials Diagnostics Enzymes Food & forage Forest & pulp Pharmaceuticals Waste management Other/generic	Agriculture Bioinformatics Biomaterials Devices Diagnostics Environment Enzymes Food and feed Forestry Pharmaceuticals R&D Service Other
Source(s)	(Suomalainen, 1979)	(Brandt, 1982; Knowles *et al.*, 1981)	(Enari, 1986)	(Enari, 1989)	(Ahvenainen, 1995; Enari, 1994)	(Schienstock *et al.*, 2001)	(Hermans *et al.*, 2006a)

R&D service is an interesting and important sub-form of biotechnology that did eventually gain momentum relatively late, but has since grown to become the third largest sub-sector of the Finnish biotechnology industry. The R&D service sector has grown from approximately 10 firms in 2005 to 47 firms in 2006. The R&D service form represents different kinds of (contract) research organizations that offer their services to mainly pharmaceutical R&D and diagnostics firms (Luukkonen, 2005). For example, a pharmaceutical R&D firm could contract with a R&D service firm for the latter to perform clinical trials related to a potential drug molecule developed by the former.

To study density-dependent entry in the heterogeneous population represented by the modern biotechnology industry in Finland, the above sub-sectors were operationalized into altogether 12 separate sub-forms. The recent descriptive studies by the Research Institute of the Finnish Economy ETLA were used as a basis for defining the sub-forms (Hermans *et al.*, 2006a; Hermans *et al.*, 2006b). However, a number of modifications were made to ETLA's classification, based on the historical literature as well as the interviews with six Finnish biotechnology industry experts. First, the Bioproduction sub-form was added, including firms that are engaged in production where either the production process or the end product of the process is biotechnological. Such firms are typically easily distinguishable as biotechnology firms, but cannot easily be fit into any of the other sub-forms. A good example is Sterol Technologies which uses biotechnological processes to produce sterols.

Second, the forestry sector of ETLA's classification was merged into the Bioproduction form, because of the nature of the biotechnological activities of the related firms. Many of the included forestry firms apply biotechnology mainly in their production processes. Third, also the Bioenergy sub-form was added, because there appears to be a small but clear set of energy related biotechnology firms that do not easily fit into any of the other categories. Table 6 below summarizes the 12 sub-forms of the Finnish biotechnology industry.

Table 6: The 12 Sub-Forms of the Finnish Biotechnology Industry

Sub-population	1st Entry	Description
Agrobiotech	1973	Firms involved with biotechnological research and production related to agriculture. E.g. genetically engineered plants.
Bioenergy	1980	Firms related to energy production through a biotechnological process. E.g. the production of natural gas by microbes.
Bioinformatics	1993	Firms specializing into applying and offering bioinformatics methods. Generally, bioinformatics involves conceptualizing biology in terms of molecules and applying techniques derived from applied mathematics, computer science and statistics to analyze and organize the related information.
Biomaterials	1982	Firms developing and producing biomaterials and related services for healthcare applications. A Biomaterial is defined as a synthetic or natural material intended to interface with biological systems to evaluate, treat, augment or replace any tissue, organ or function of the body. E.g. bioactive glass, tissue engineering, and implants.
Bioproduction	1973	Any firms not fitting into any of the other sub-populations, but clearly engaged in production where either the production process or the end product of the process is biotechnological.
Devices and Equipment	1973	Firms developing and producing different devices and equipment used in biotechnical research or -production processes.
Diagnostics	1974	Firms developing and producing biotechnology related medical diagnostics methods, devices and services thereof. Also different biosensors are included.
Environment	1979	Firms related to biotechnological methods and processes in improving the state of the environment, e.g. waste management.
Enzymes	1976	Firms related to biotechnological development and production of enzymes, to be used as raw material by mainly industrial and pharmaceutical companies.
Food and Feed	1974	Firms using biotechnological processes for developing and producing functional foods and animal feed.
Pharmaceutical / therapeutic	1973	Firms related to biotechnological development of pharmaceuticals and other related medical therapies
R&D Service	1973	Firms that offer biotechnology related R&D services to other companies. E.g. pre-clinical drug test services for the pharmaceutical industry.

The related sub-populations have developed through differential evolutionary paths, as can already be seen from the years of first entries. Figure 4 and Figure 5 below show the annual level densities and entry rates of the twelve sub-populations, respectively. From Figure 4, it can be noted that the sizes of the different sub-populations vary substantially, as well as their temporal paths of evolution. Many of the healthcare related sub-populations have experienced a strong growth between 1990 and 2000, while virtually all sub-populations have faced a considerable slowdown in growth after 2000. The exceptionally fast upsurge of the R&D Service firm population is also clearly visible. It can also be noted that several of the more traditional areas such as Food & Feed, Environment, and Enzymes, have faced an even longer period of slow decline in density. The entry rates shown in Figure 5 show very strong levels of annual variation, ranging from zero entries up to 12 annual entries for some of the sub-populations.

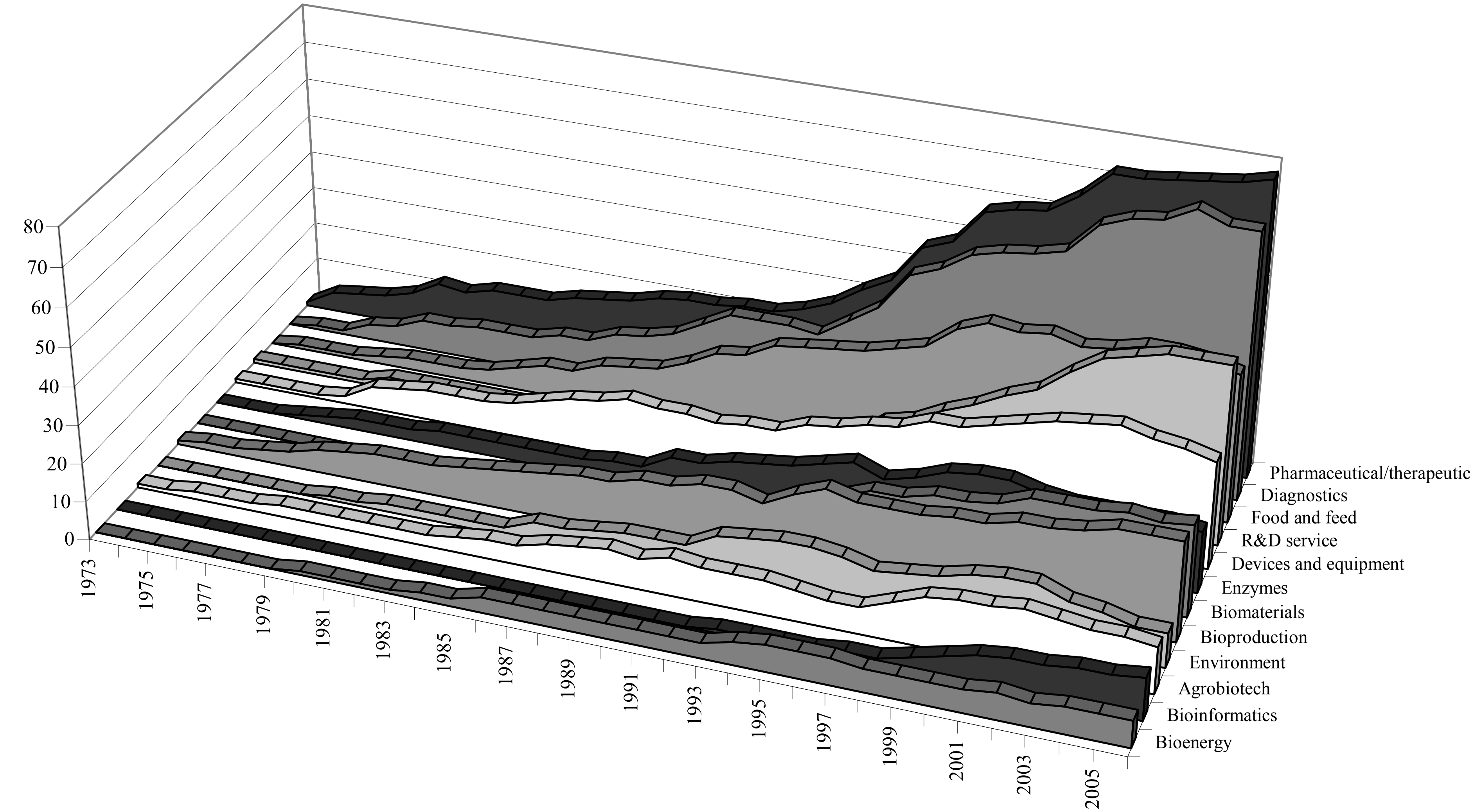

Figure 4: Densities of the Sub-Populations of the Finnish Biotechnology Industry

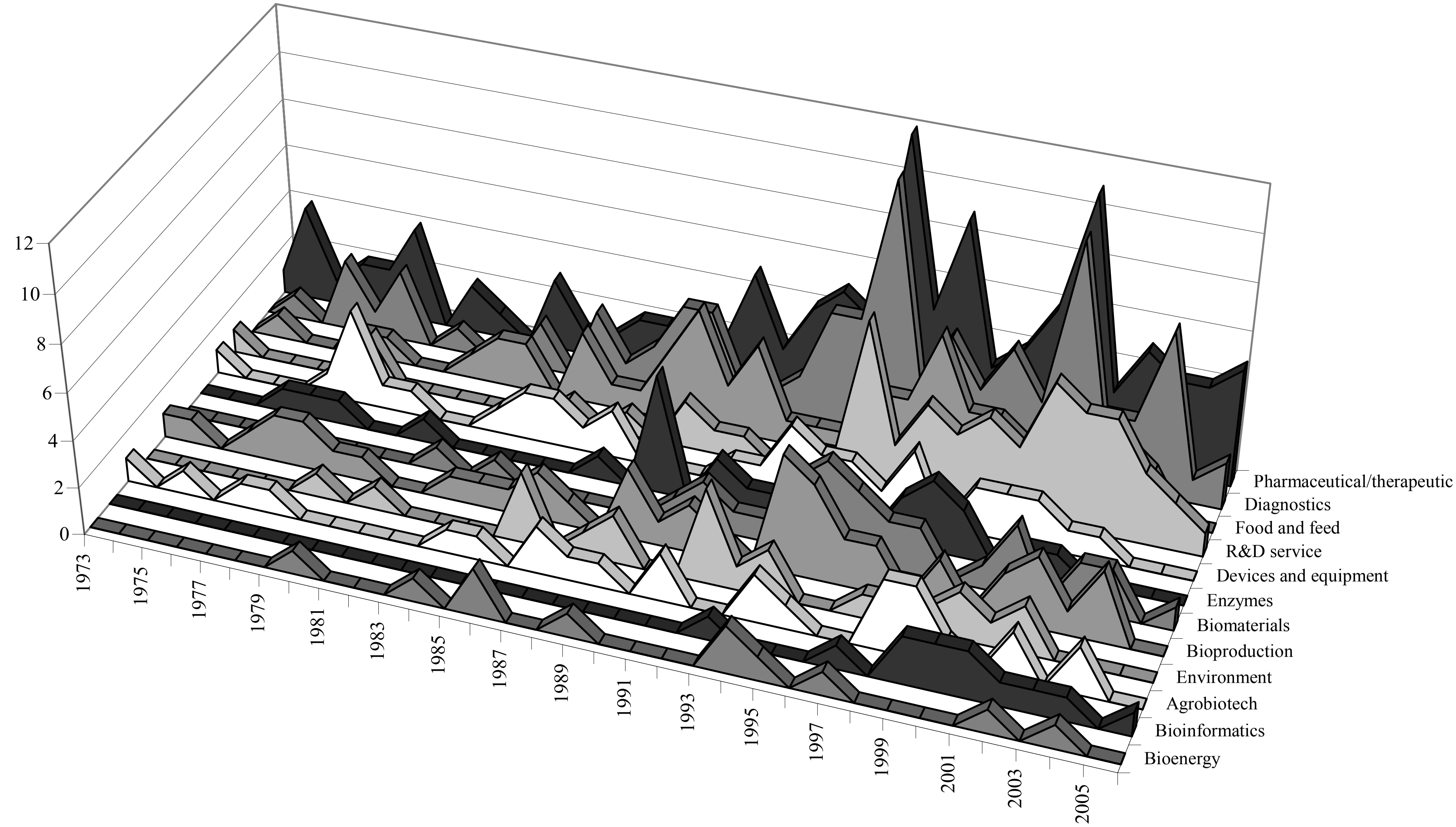

Figure 5: Entries to the Sub-Populations

4.4 Clusters of Sub-Forms

Most of the 12 sub-forms can also be grouped into a small number of higher level *clusters* of sub-forms. The clusters represent an intermediate level of aggregation between the main form and the individual sub-forms (see also Figure 9 on page 103). In essence, a cluster groups together those sub-forms that are similar to each other on a relevant dimension from the identity perspective. Even though organizations belonging to the same cluster may represent different sub-forms (e.g. pharmaceuticals vs. diagnostics), they may still share some common features (e.g. internal competence base), external relationship structures (e.g. to regulating authorities) and activities (e.g. a common industry association promoting healthcare related biotechnology). Thus the externally enforced identities of such sub-forms are partially overlapping and can be meaningfully grouped on the cluster level.

Within the Finnish biotechnology industry, perhaps the most salient cluster can be labeled as "Healthcare Biotechnology". As the name implies, this cluster combines those sub-forms whose activities are predominately related to healthcare. By definition, the Pharmaceutical/therapeutic, Diagnostics, and Biomaterials sub-forms readily fall into this cluster. Two additional sub-forms, Bioinformatics and R&D Service are also included. In principle, the computational methods and technology of bioinformatics could well be used in non-healthcare applications as well. However, a quick glance over the group of Finnish bioinformatics firms reveals that a majority of the bioinformatics activity is organized around the healthcare sector, mainly drug development. Biocomputing Platforms, Fatman Bioinformational Designs, and Triacle Biocomputing are firms that exemplify this tendency. A similar argumentation can be presented for the R&D service firms. Again, a clear majority of these firms are focusing on the healthcare sector in Finland (cf. Luukkonen, 2005).

A second cluster combines the industrial applications of biotechnology, labeled as

"Industrial Biotechnology". This cluster includes the sub-forms Bioenergy, Bioproduction, Environment, and Enzymes. The activities of the firms representing these sub-forms fall closer to the upstream of the general value chain. Both the firms themselves as well as their customers are often large industrial organizations with a strong focus on industrial production. A third cluster is formed around the Agrobiotech and Food and Feed sub-forms, titled "Agro-food-feed". Finally, Devices and equipment is a special sub-form in the sense that it doesn't clearly fit into any of the above clusters. Rather, the sub-form includes a combination of firms that supply biotechnological equipment to practically any of the other sub-forms. Thus the Devices and Equipment sub-form also defines a cluster that includes no other sub-forms.

Table 7 summarizes the above clusters and their constituent sub-forms. This division into clusters is in line with the classification of "fields of application" of the Finnish biotechnology industry by Hermans, Kulvik and Tahvanainen (2006a). Additionally, a central biotechnology industry organization in Europe, EuropaBio, uses a corresponding scheme for broadly classifying commercial activities in biotechnology. EuropaBio uses the labels Healthcare Biotechnology (or alternatively Red Biotechnology), White Biotechnology, and Green Biotechnology, respectively, to refer to the three first clusters presented in Table 7[9].

[9] EuropaBio's classification can be found at http://www.europabio.org/.

Table 7: The Operationalization of Clusters of Sub-Populations

Cluster	1st Entry	Included Sub-Populations
Healthcare biotechnology	1973	Bioinformatics Biomaterials Diagnostics Pharmaceutical/therapeutic R&D Service
Industrial Biotechnology	1973	Bioenergy Bioproduction Environment Enzymes
Agro-Food-Feed	1973	Agrobiotech Food and Feed
Devices and Equipment	1973	Devices and Equipment

Figure 6 and Figure 7 below show the cluster level evolution of the Finnish biotechnology industry. Again, the relatively rapid growth of the Healthcare cluster can be clearly observed. The Industrial Biotechnology and Agro-Food-Feed clusters have evolved in approximately equal levels. Similar to the individual subpopulations, the cluster level rates of entry have a high variance.

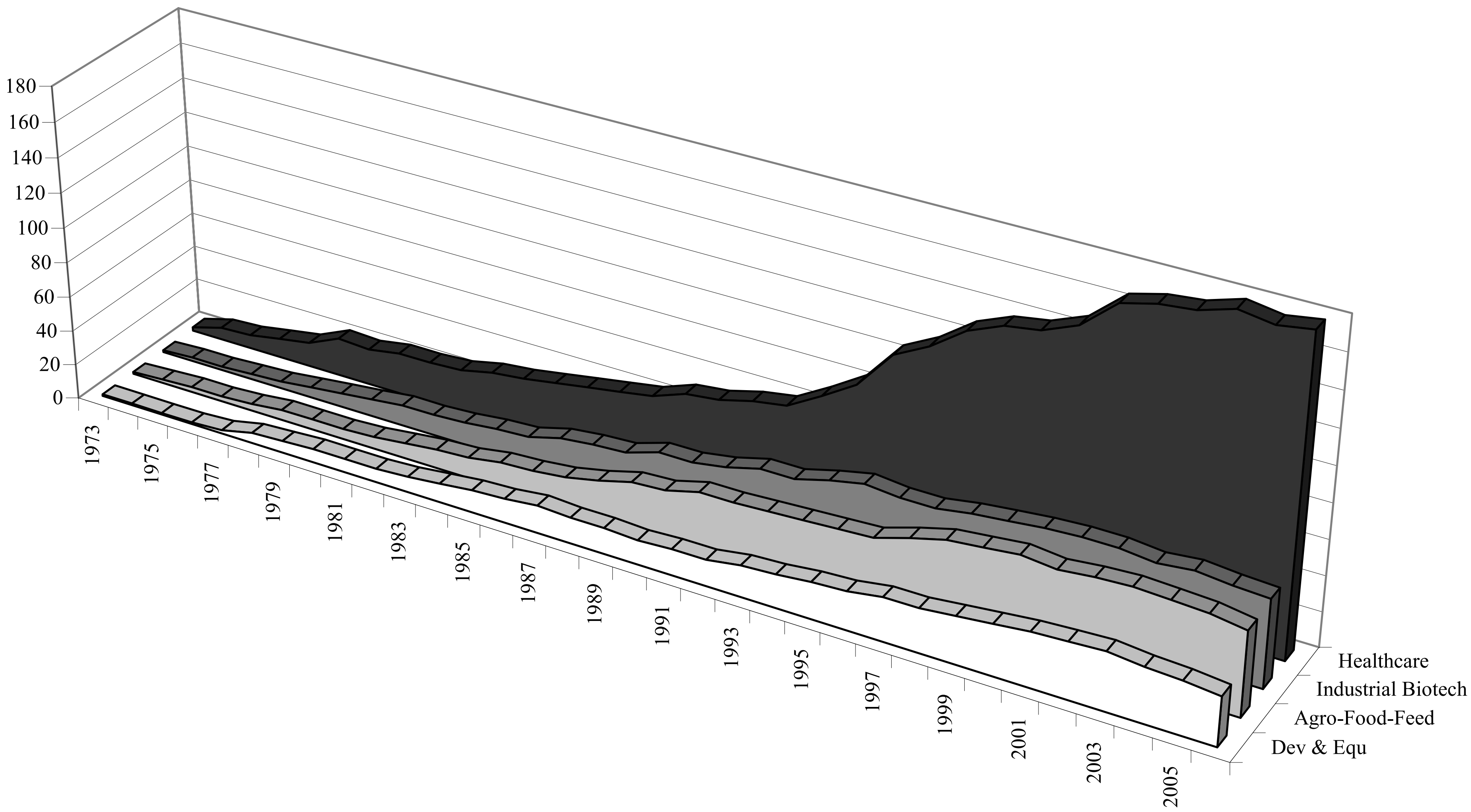

Figure 6: Cluster Level Density

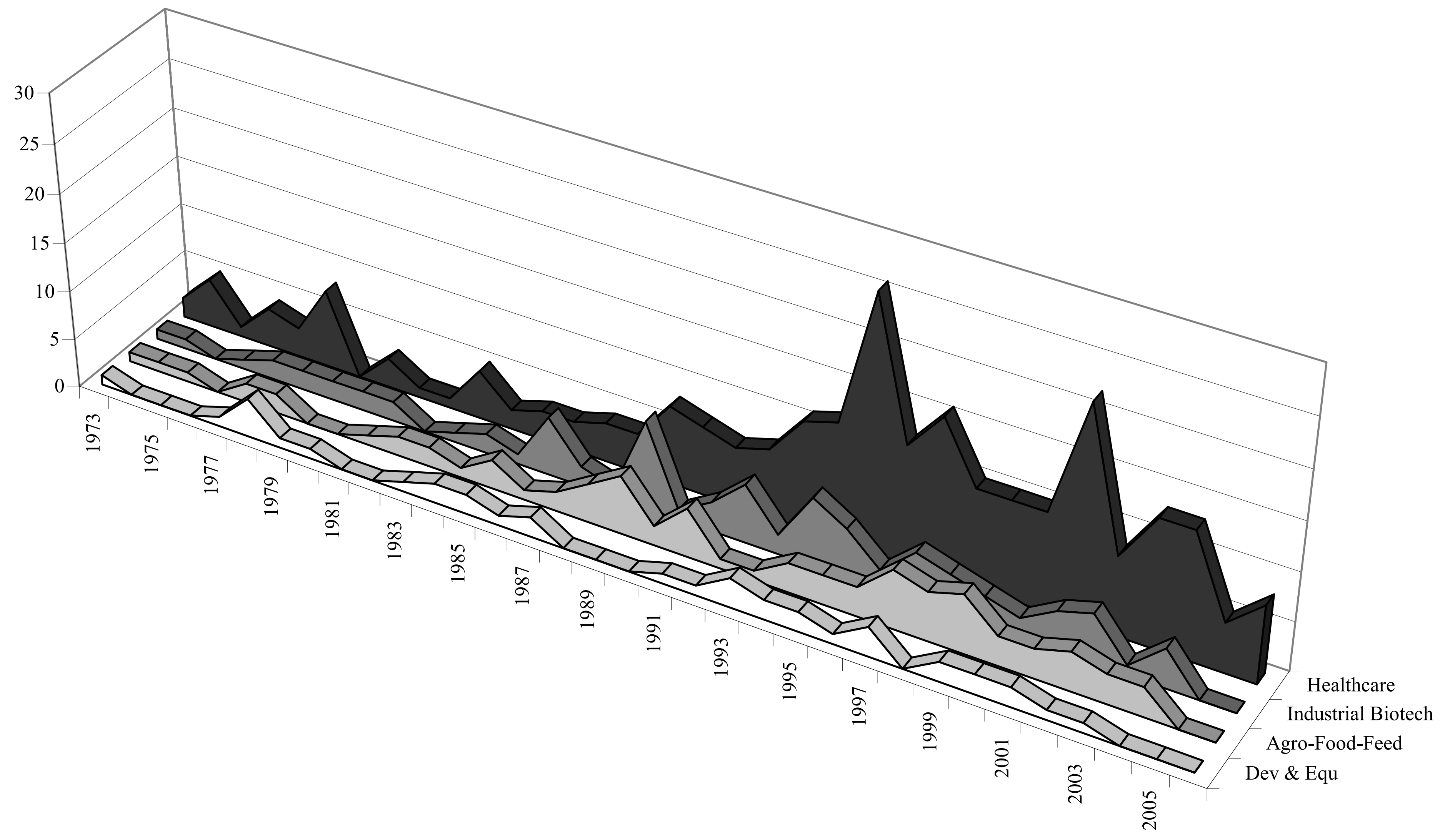

Figure 7: Cluster Level Entries

5 Data and Methods

To test the hypotheses of density-dependent entry in heterogeneous populations, a wide array of sources was triangulated to compile a comprehensive dataset that covers the entire biotechnology industry in Finland between 1973 and 2006. The present chapter describes the data and methods used, and is organized into three sections. First, the process of data collection is described. This is followed by a description of the variables used, including related descriptive statistics. The final section describes the modeling approach was used in testing the hypotheses.

5.1 Data

In organization research, many existing studies of the biotechnology industry have concentrated on a single segment often called "human therapeutics and diagnostics" (e.g. Lane *et al.*, 1998; Powell *et al.*, 1996; Powell *et al.*, 2005; Stuart *et al.*, 1999). However, given the objectives of the study, the aim was to include a wide array of biotechnology firms that cover all relevant sub-forms within the Finnish biotechnology industry. Only for-profit organizations with biotechnology-related core activities were included in the analysis. In other words, university departments, public research institutes, and other non-commercial organizations were excluded. Both newly founded dedicated biotechnology firms (de novo entrants) as well as existing companies entering the biotechnology industry from other fields (de alio entrants) were included.

The data collection process was staged into three phases. The first phase involved the identification of *all* biotechnology firms that have operated in Finland during the period 1973-2006. The OECD definition of biotechnology (OECD, 2004) was used as the general basis for identifying biotechnology firms. Second, the obtained list of

Finnish biotechnology firms was appended with data from diverse additional sources to obtain as accurate as possible information regarding the entry and exit of the firms, as well as their membership in the sub-populations of the industry. During the second phase, all included firms were coded into one or more of the twelve individual sub-populations described in Table 6 above. The third phase involved a special card-sorting technique in interviews with six Finnish biotechnology industry experts to verify the coding of the data.

5.1.1 Phase I: Identification of the Entire Population

To come up with as comprehensive a list of Finnish biotechnology firms as possible, several sources were triangulated. Different biotechnology firm listings were used as a starting point. The *Index of Biotechnology Companies, Organizations and Research Institutes in Finland* published annually by the Finnish Bioindustries association (FIB) in 1997-2006 proved to be clearly the most comprehensive source[10]. For each firm, the FIB index records the founding date, a short description of the firm's activities, contact information, as well as additional descriptive information. The FIB index also features a detailed scheme for classifying the firms into sub-sectors of biotechnology, which was very helpful in the firm-level coding. However, the FIB index also has a few shortcomings. First, the historical coverage of this source is limited to 1997. Thus some 25 years of the era of modern biotechnology in Finland remains left censored – at least for firms that have experienced an exit before 1997. Second, for firms that have experienced an exit between 1997 and 2006, the exact exit dates are not recorded. Instead, such firms just disappear from the subsequent versions of the index. Third, inclusion in the FIB index is subject to the individual firms' own effort in subscribing themselves to the index. Thus, despite fairly good coverage, several biotechnology firms could be identified that are not shown by any editions of the FIB index.

Several international biotechnology firm listings were also investigated, such as the Bioscan Directory (published by Thomson BioWorld), several volumes of the International Biotechnology Directory by Coombs (1984; 1986), as well as the Genetic Engineering and Biotechnology Firms Worldwide Directory of 1983/1984 and 1985 (published by Sittig & Noyes). However, all such international sources turned out to be severely limited in their information concerning the Finnish biotechnology industry. For example the Genetic Engineering and Biotechnology Firms Worldwide Directory contained only 11 Finnish firms in 1985 while the final database used in this study records a total of 70 firms in 1985. The Coombs International Biotechnology Directory lists a somewhat higher number of firms in 1984 (38 to be exact), but many of these are consultancies or non-biotechnology related chemicals or equipment suppliers that were not recorded as biotechnology firms in the final database.

To patch the problems of historically incomplete information and lack of coverage of the industry directories and indices, additional sources were used in identifying possibly missing biotechnology actors. First, all biotechnology related articles and news published in *Kemia-Kemi* during its entire history of publication, 1974-2006, were screened for possibly missing firms. Kemia-Kemi is the leading Finnish (bio)chemistry oriented, semi-academic industry journal that has been published in 8 to 12 annual issues. Kemia-Kemi has constantly featured related articles and entire special issues in biotechnology, including topics ranging from industry news to market trends to technological developments. Also several academic articles have been included that present results from scientific research. Altogether 1440 biotechnology related articles were included from Kemia-Kemi. Most of the identified articles mention one or more firms operating in the Finnish biotechnology industry.

Using a similar procedure, all biotechnology related articles and news published in *Kauppalehti* in 1973-2006 were screened. Kauppalehti is the leading general trade

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[10] The most recent version of the FIB index is freely available at http://www.finbio.net/. The historical editions were obtained from the archives of FIB.

newspaper in Finland, published in approximately five issues per week. Altogether 1142 biotechnology related articles were included from Kauppalehti. A final source for triangulating biotechnology firms was patent data. All biotechnology patents granted in Finland between 1970 – 2006 were screened. The patent data was obtained from the Esp@cenet database offered by the Finnish patent authorities. The definition of biotechnology patent classes by OECD was applied (OECD, 2004). Altogether 381 biotechnology patents granted to Finnish firms in Finland were screened.

5.1.2 Phase II: Firm Level Coding

The second phase in the data collection included one-by-one manual identification and coding of the entry and exit dates for each of the firms included, as well as the sub-population(s) they belong to. Again, several sources were triangulated to obtain as accurate firm level information as possible. To begin with, all firm level data readily available from the company directories and newspaper and journal articles was included and coded.

After this, all of the recorded firms were run through the company databases of the National Board of Patents and Registration of Finland (NBPR). NBPR maintains a record of all corporations and other legal entities operating in Finland. NBPR registration is required by law. Thus, by definition, NBPR holds a record of every company that operates or has operated in Finland, including basic data such as founding and disbanding dates, as well as mergers with other entities. The entry dates for all firms founded after 1972 were obtained directly from NBPR. Similarly, all exits between 1973 and 2005 were coded from the same source. Finally, the data was supplemented with factual information from the interviews of Finnish biotechnology industry experts, information publicly presented by the firms themselves, as well as – when necessary – targeted searches from news databases using the firm names. For some firms, the news searches proved to be an extremely good source for understanding the activities and historical development of the firms.

Several rules were applied in coding the firm level data. First, standard rules for coding entries, exits, mergers, acquisitions and so forth in ecological studies were applied (e.g. Carroll *et al.*, 2000a: 101-110). For example, Contral Pharma and Carbion were merged to Biotie Therapies in 2002, but the company continued operations with the Biotie name and identity. Thus, two exists but zero entries were coded for these firms in 2002. Had there been a clear change in firm identity (and form), then three exits and one entry would have been coded.

Second, membership in multiple sub-populations was allowed. Approximately one quarter[11] of the included firms were such that they had activities in two or more of the sub-forms – and were identified accordingly by different sources. This tendency to spread across form boundaries is clearly visible for example in the classification of the firms in the FIB index. Similarly, the trade newspaper and industry journal articles as well as expert interviews confirmed this. In many cases, it is a deliberate strategy even for newly founded firms to set up simultaneous operations in several areas to balance risk and secure the required levels of income (cf. Luukkonen, 2005). A good example of this is Finnzymes, which has built strong operations and importing and reselling reagents and enzymes to other companies in Finland. Simultaneusly, Finnzymes has been able to invest heavily – thanks to the generated income – in the research and development of their proprietary diagnostics applications (Ojanperä, 2000).

Third, a special method was used for recording the entry of firms founded before 1973. Since the beginning of the modern biotechnology industry was operationalized to 1973, all firms legally established before this were treated as de alio entrants, i.e. firms entering the biotechnology industry after operating in some other field first. The entry of the de alio firms were timed to the date when they were first mentioned in any of the aforementioned sources (excluding NBPR). A good example of such firm is the largest Finnish pharmaceutical company Orion, which was originally established in 1917.

[11] Of the 401 firms in the final database, 84, 17, 6, and 1 firms were members in two, three, four and six sub-populations, respectively. Together these represent a little more than one quarter of all of the firms.

The first products of Orion included sugar surrogate, Lysol, ammonia, as well as rifle oil. Today, Orion is generally identified as a biopharmaceutical company. The entry of Orion to modern biotechnology was coded to 1974 after a Kemia-Kemi news article related to Orion and the biological production of antibiotics. The entry of altogether 36 de novo firms was coded using a similar rule. Thus, less than 10% of the firms in the database are de alio entrants.

Finally, all conflicting or otherwise doubtful information was investigated case-by-case. In such cases, information from different sources was prioritized in the following order. The documentation supplied or published by firms themselves was considered as most accurate (i.e. published company histories, annual reports and the like). For company entries and exits, information from NBPR was considered as most accurate. Thereafter, any factual data obtained from industry experts was considered as next most accurate. In some cases, mostly related to the largest firms, company representatives had to be eventually contacted separately to obtain specific details. Finally, after the above sources, information published in other sources such as the FIB index or newspaper and/or journal articles was considered.

5.1.3 Phase III: Verification of the Data

After the data collection process and the triangulation of sources described above, the coding of the firms' membership in different sub-populations was tested with the interviews of six industry experts, using a special card-sorting technique. The included industry experts represent the following positions: a director in a large pharmaceutical company, the CEO of a major Finnish biotechnology industry association, the business development manager of a midsize biotechnology firm, a biotechnology investment manager from a venture capitalist organization, a biotechnology industry expert representing the national center of excellence program, as well as a professor of biotechnology and bioprocess engineering.

Following previous research (Gulati, 1995; Lane *et al.*, 1998), the respondents were given a set of cards, each containing the name of a single firm, covering the whole population of Finnish biotechnology firms. The respondents were asked to go carefully through the cards and sort them into different piles according to their best knowledge. First, a respondent needed to identify whether (s)he was familiar with the firm in the first place. The cards representing unknown firms were put aside to a separate pile. To increase the robustness of the results, those firms with only a familiar name were asked to be sorted as unknown as well. Second, the respondents had to identify whether they saw a firm as a biotechnology firm at all. Again, a separate pile was used for non-biotechnology firms.

For any cards passing the above screens, the respondents needed to either sort them directly into one of the piles representing the twelve sub-forms, or to a pile titled as "multiple fields". A second round was run on the latter pile to carefully record the different sub-populations those firms were members of. All respondents sorted a majority of the firms directly into a single sub-population. The respondents also had a pile called "change in sub-field" where they were asked to put any firms that had experienced a major change in their focal area(s) of operation. Only four firms were reported to have a major change in their focus. Finally, the respondents were also instructed to talk through their sorting, so that the researcher could make notes of any specific reactions and details.

The original coding in the database was tested against the results of the card-sorting exercise. The following assumptions were made. First, all firms not familiar to any of the interviewed industry experts were excluded from the comparison. Second, only such firms were included that at least one respondent considered as a biotechnology company. Finally, a match was recorded if any of the respondents had placed the firm into (one of) the sub-population(s) coded in the database. This way, a total of 317 firms were included in the comparison, yielding a 84% match between the original coding and the industry expert responses. The analysis was also further narrowed to those 270 firms that were familiar to at least two respondents, thus improving the reliability of the interview results. In the latter comparison, a 87% match was found. These measures show a generally good level of match and thus verify the robustness of the original coding[12]. Moreover, they are generally in line with earlier research using similar methodology (Lane *et al.*, 1998).

A possible limitation of the data is that the coding approach does not incorporate an easy way to account for cases where a firm has a major change in its focus of activities and thus its membership in the sub-populations. Fortunately, only a very small number of such cases were identified (as shown also by the interviews), thus enabling their processing case-by-case. If the change involved an organizational change (e.g. a spin-off or split-up) and a major shift in the focus of activity, then an exit and an entry were coded for the old and new firm, respectively. If no organizational changes were involved, and the activities were shifted to an adjacent field, then both the old and new sub-population was coded simultaneously.

Based on the above it can be assumed that the data gives a reliable and detailed historical description of the Finnish biotechnology industry in 1973-2006 .

5.2 Variables

Following existing ecological research, the dependent variable used in modeling density-dependent entry into the Finnish biotechnology industry was the rate of entry of biotechnology firms, specified at the levels of the main population (λ_{main}) and the individual sub-populations (λ_i). Following the standard convention, the entry data was pooled into annual levels and thus the entry variables measure annual entry rates. For

[12] Interestingly, for a number of the firms showing a mismatch, factual data exists that directly confirms the original coding, thus further strengthening its robustness. A good example of such a case is DN Bioprocessing which two of the respondents had identified and sorted into Diagnostics and R&D service, respectively. However, from several news articles it can be noted without doubt that the firm has concentrated on developing a new method for processing dump waste and producing biogas thereof. Thus this firm had been properly coded into the Environment and Bioenergy sub-populations in the original coding, still showing a mismatch.

the main population, the data covers entry rates between 1973 and 2006, yielding a total of 34 spells. The entry rates of the twelve sub-populations, covering their years of existence until 2006, were pooled together to form a total of 361 spells. The pooling is necessary for capturing the effects across the whole system of sub-populations.

It has become customary in ecological research to measure the effects of legitimation and competition in terms of density, i.e. the number of organizations within a population (cf. Carroll *et al.*, 1989c, 2000a: 214; Zucker, 1989). To test whether the relationship between density and entry rate has the shape of an inverted U, both the linear and the squared versions of the density variable were included. The simultaneous estimation of parameters for both linear and squared density variables allows for (but doesn't force) the nonmonotonic inverted U shape relationship between density and entry rate. This way, the effects of legitimation and competition (linear and squared, respectively) can also be separated from each other. If the theory holds, the linear and squared density variables should be significant and have positive and negative coefficients, respectively.

The density variables used in this study are specified at three levels of analysis. Based on the systems approach to organizational forms, a hierarchical structure was assumed between the different levels. First, a simple system was assumed with the twelve sub-populations nested directly under the main population (see Figure 8 below). In this system, density is specified at two levels: main population density (N_{main}) and sub-population density (N_i). After this, one level of complication was added, yielding a system where clusters of sub-populations appear hierarchically between the main population and the individual sub-populations. In this systemic structure, the sub-populations are nested under the clusters and the clusters again under the main form (see Figure 9 below). Thus, cluster density is also included as an independent variable (N_{cl}).

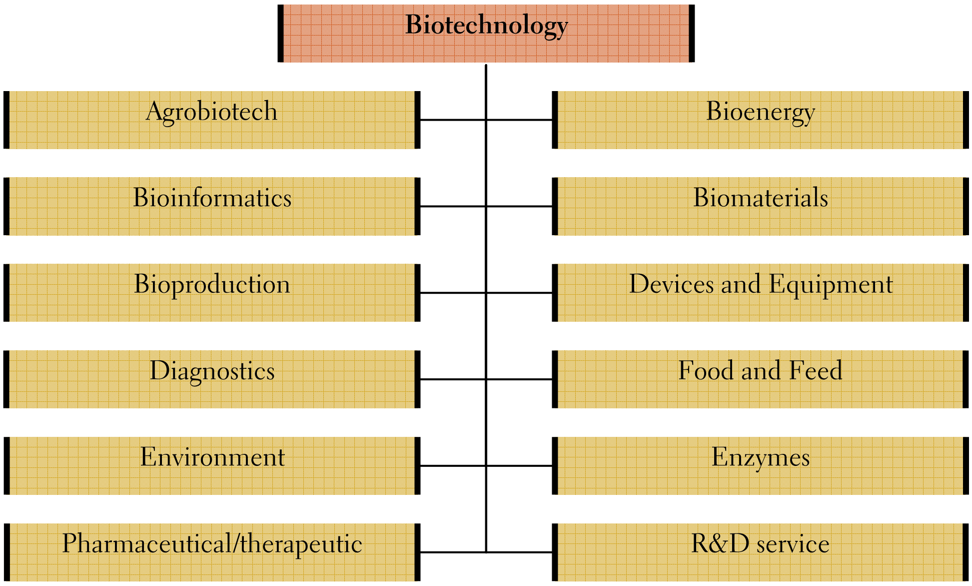

Figure 8: Hierarchical System: Main Population and Sub-Populations

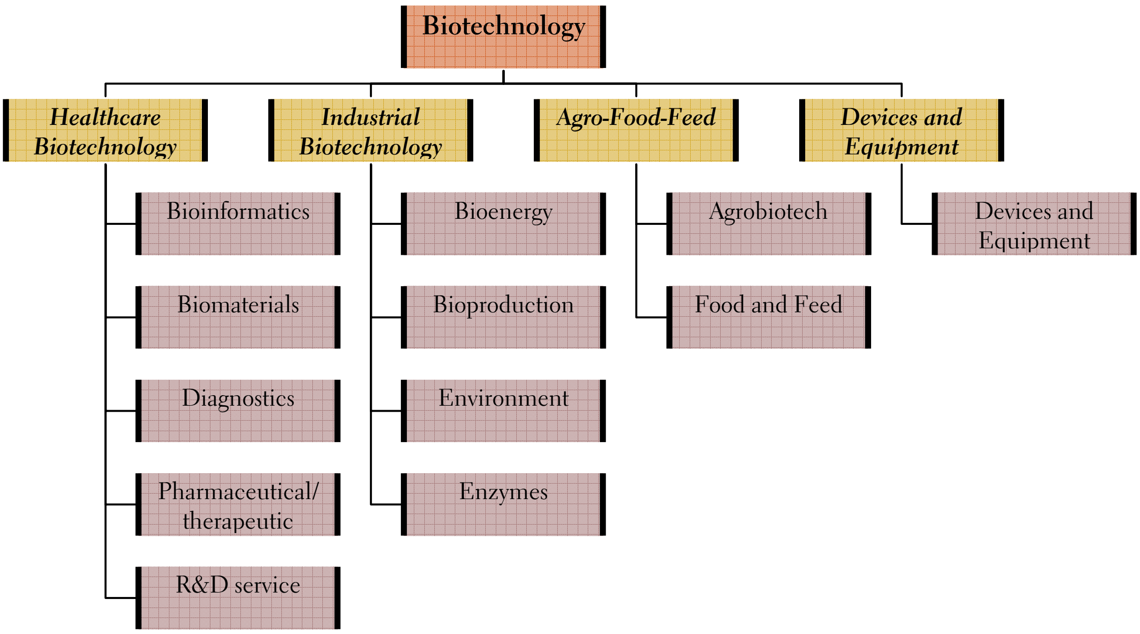

Figure 9: Hierarchical System: Main population, Clusters, and Sub-Populations

Three important issues should be considered regarding the operationalization of the density variables. First, simultaneous membership in multiple sub-populations was allowed. Thus, a single firm may contribute to the densities of more than one sub-population. However, when calculating the cluster and main population densities, each firm was allowed to contribute only once per cluster and the main population. Two alternative approaches were also considered, but were found to be problematic. The first option was to force a firm to be a member in only one sub-population, representing the strongest field of operation of the firm. However, the identification of the strongest field was found to be very difficult in many cases. Moreover, valuable additional information would be lost this way. The second alternative would have been the division of a firm's unit density between the different sub-populations (e.g. 50% to Pharmaceutical/ therapeutic and 50% to Diagnostics). Again, this approach was found to be problematic because it would probably underestimate the density-dependent effects of some firms – in comparison to the single-population firms.

Second, to account for the varying sizes of the individual sub-populations, sub-population density was standardized to the scale [0, 1] according to the minimum and maximum absolute densities of the individual sub-populations. Because the sub-population densities were pooled together for parameter estimation, using absolute sub-population densities would have implicitly assumed equal sizes for the sub-populations in the estimation. In other words, the models would have forced the turning point of the inverted-U shaped entry-density curve of each sub-population to occur at the same absolute level of density. In reality, however, the maximum densities of the sub-populations range from 7 (Bioenergy) to 78 (Pharmaceutical/therapeutic). The same rule was applied also for cluster density. Absolute density values were used only for the main population.

Using the observed maximum density as the basis for the standardization is not ideal, either. This is because the different sub-populations might be in different stages of their development, and thus the observation window might censor their true maximum density. However, this was clearly the best available basis for the standardization.

Moreover, a majority of the sub-populations had experienced their peak densities (at least local ones) between 2002-2004, followed by a number of years of declining density.

The use of absolute density measures was tested in multiple density-dependent models with the pooled density variables. However, even the simplest models, including only sub-population density, did not yield any robust results. On the other hand, replacing absolute density with standardized density in the same models yielded robust results that were in line with the theory. In addition, the standardization is generally in line with other recent attempts to use weighted density to make the density variables more robust (e.g. Bogaert *et al.*, 2006).

A third point to note is that the main population density and cluster density variables (N_{main} and N_{cl}, respectively) were not specified net of the density of the focal sub-population. In other words, the density of the focal sub-population was counted into the higher level density variables. Despite the increased risk for multicollinearity[13] (Hair *et al.*, 1998: 2), this approach enables one to more accurately determine from which level the effects of legitimation and competition truly originate from. Moreover, the general principles of ecological theory maintain that density should be counted for a complete, relevantly defined population (Hannan *et al.*, 1989). If the density of a single sub-population would be subtracted, one would be talking of a different, only partial measure of density at the cluster and main population levels. This would raise questions of validity with regards to the theoretical arguments.

In addition, the subtraction of the density of the focal sub-population from the higher level density variables would bring no additional variables into the specifications, and

[13] The possible existence of multicollinearity was examined through two tests. First, the models were re-estimated with a modified cluster density variable that was calculated net of the density of the focal sub-population. The results were materially the same as in the original models, thus proving that the original results were not affected by multicollinearity. As a second test, outliers were removed from the data by using a Winsoring algorithm (STATA command WINSOR). This operation didn't affect the results either, thus again disproving the existence of a multicollinearity problem.

thus the estimated statistical models would remain mathematically equivalent to the ones with gross density variables. Only the interpretation of the coefficients would become slightly different. In essence, the renewed interpretation would relate to what kind of density-dependent effects do the *other* sub-populations have on a particular sub-population. To be strict, this is in partial disagreement with the original theoretical idea of looking at what density-dependent effects does the cluster or the main population as a *whole* have on the entry rate within a particular sub-population.

Consider next the control variables. Population age is often used as an independent variable in the estimations of density-dependent models (Cattani *et al.*, 2003; Hannan, 1997; Wezel, 2005), though not always (Cattani *et al.*, 2003; Greve, 2002a). In this study, the age variables were specified at the sub-population (T_i) and main population level (T_{main}). Cluster age would have essentially been equal to main population age, and thus it was excluded. To add, the main population age was found to be of very little use because of its high correlation with the density variables, especially main population density. Thus sub-population age remained the only relevant alternative. However, because of relatively high correlations, as well as for the sake of parsimony, the sub-population age variable T_i was excluded from most of the specified models. Some of the models including cluster density did not converge without the age variable. Thus, sub-population age was included in those models. The age variable was also tested with the other models, and its exclusion did not cause any substantial changes in the effects.

Following extant density-dependence research (e.g. Cattani *et al.*, 2003; Hannan, 1997; Wezel, 2005), several control variables were also included. To control for the general economic environment, the gross domestic product of Finland was included (*GDP*)[14]. The linear and squared entries of the previous period ($Entries_{t-1}$ and $Entries^2_{t-1}$) were included to control for the endogenous effects caused by high peaks in previous year's

[14] Total GDP, in millions of 2006 US$ (converted to 2006 price level with updated 2002 EKS PPPs). Obtained from The Conference Board and Groningen Growth and Development Centre, Total Economy Database, March 2007, http://www.ggdc.net.

entries. Finally, six period variables were included to account for changes and discontinuities in the institutional environment. The first two dummy variables (*Recession 1* & *Recession 2*) were set to control for the economic recessions in 1976-1977 and 1990-1993 (zero or negative growth of Finland's GDP). Four additional periods were included to account for the discontinuous effects in the institutional environment as described in the previous chapter. The first (*P1*) was set to 1 from 1978 onwards, capturing the corresponding discontinuous developments in technology and the institutional environment for biotechnology. The second period (*P2*) marks the effects of increased funding and sociopolitical legitimation caused by the several biotechnology programs launched in 1988. The third period (*P3*) captures a major change in the regulatory environment, as Finland joined the European Union in 1995. Finally, *P4* captures the post-2000 period of declining funding and public attitude, as well as the slowdown in the worldwide economy after the 1999-2000 general overheating. Table 8 below presents summary statistics and correlations for the included variables.

Table 8: Descriptive Statistics and Correlations

Variables	Obs.	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
(1) N_i	361	0.46	0.33	0.00	1.00	1.00																
(2) N^2_i	361	0.32	0.34	0.00	1.00	0.97	1.00															
(3) N_{cl}	361	0.50	0.34	0.00	1.00	0.95	0.92	1.00														
(4) N^2_{cl}	361	0.37	0.36	0.00	1.00	0.94	0.95	0.97	1.00													
(5) N_{main}	361	132.07	88.13	0.00	269.00	0.91	0.89	0.97	0.95	1.00												
(6) N^2_{main} / 1000	361	25.19	25.66	0.00	72.36	0.88	0.91	0.93	0.96	0.97	1.00											
(7) T_i	361	15.09	9.38	0.00	33.00	0.87	0.82	0.86	0.82	0.87	0.83	1.00										
(8) T_{main} (not used)	361	17.91	9.38	0.00	33.00	0.89	0.85	0.96	0.91	0.98	0.93	0.88	1.00									
(9) $Entries_{t-1}$	361	1.47	1.83	0.00	12.00	0.32	0.28	0.28	0.24	0.32	0.28	0.39	0.30	1.00								
(10) $Entries^2_{t-1}$	361	5.53	14.93	0.00	144.00	0.21	0.19	0.19	0.16	0.23	0.21	0.28	0.21	0.88	1.00							
(11) GDP	361	127.31	29.94	80.38	188.52	0.88	0.87	0.93	0.92	0.97	0.95	0.86	0.97	0.25	0.18	1.00						
(12) Recession 1	361	0.04	0.21	0.00	1.00	-0.26	-0.20	-0.29	-0.22	-0.29	-0.21	-0.28	-0.33	-0.11	-0.06	-0.32	1.00					
(13) Recession 2	361	0.12	0.33	0.00	1.00	-0.04	-0.12	-0.03	-0.12	-0.05	-0.16	0.02	0.02	0.01	-0.03	-0.07	-0.08	1.00				
(14) P1 (1978-)	361	0.90	0.30	0.00	1.00	0.41	0.31	0.45	0.33	0.46	0.32	0.46	0.55	0.16	0.10	0.49	-0.66	0.12	1.00			
(15) P2 (1988-)	361	0.62	0.49	0.00	1.00	0.74	0.67	0.81	0.72	0.82	0.71	0.75	0.85	0.31	0.21	0.77	-0.27	0.30	0.42	1.00		
(16) P3 (1995-)	361	0.40	0.49	0.00	1.00	0.80	0.82	0.86	0.88	0.89	0.90	0.74	0.83	0.33	0.26	0.82	-0.18	-0.31	0.27	0.64	1.00	
(17) P4 (2001-)	361	0.20	0.40	0.00	1.00	0.67	0.74	0.68	0.77	0.73	0.83	0.61	0.67	0.13	0.10	0.77	-0.11	-0.19	0.16	0.39	0.61	1.00

5.3 Modeling Frameworks

In line with earlier research, the density-dependent entry of organizations was modeled as an arrival process (e.g. Ranger-Moore *et al.*, 1991; Wezel, 2005). According to the modeling strategy, the arrival rate (i.e. entry rate) specified at the levels of the main population and the sub-populations is affected by the independent variables, period effects and other covariates (Lomi, 2000). For such arrival processes with an integer dependent variable, Poisson regression would normally represent the best method for data analysis (Cattani *et al.*, 2003). However, Poisson regression becomes non-robust if the variance of the dependent variable exceeds its mean - a problem called overdispersion (McCullagh *et al.*, 1989: 198-200). Overdispersion does not affect the coefficient estimates themselves, but the standard errors might be underestimated, thus making chi-square values over-estimated (Wezel, 2005).

Negative binomial regression is able to adequately overcome the problem of overdispersion (Cattani *et al.*, 2003). In this approach, a stochastic error component is added to the model. The error component has a Gamma distribution that enables the parametrization of overdispersion (Wezel, 2005).

Two different negative binomial regression models were used in testing the hypotheses[15]. Hypothesis H1a was tested with a standard negative binomial regression model specified at the main population level, as follows:

$$\lambda_{main}(t) = \exp(\alpha_1 N_{main,t-1} + \alpha_2 N^2_{main,t-1} + \pi' p_t + \xi' z_t) \cdot \varepsilon_t \,. \qquad [9]$$

[15] The used models generally correspond to the Generalized-Yule model used in some density-dependent studies (e.g. Hannan et al., 1995b; Hannan, 1997).

The rest of the hypotheses were tested with the following fixed effects negative binomial regression model, specified at the sub-population level:

$$\lambda_i(t) = \exp(\alpha_1 N_{main,t-1} + \alpha_2 N^2_{main,t-1} + \beta_1 N_{cl,i,t-1} + \beta_2 N^2_{cl,i,t-1} + \gamma_1 N_{i,t-1} + \gamma_2 N^2_{i,t-1}$$

$$+ \delta T_{i,t} + \pi' p_t + \xi' z_t) \cdot \varepsilon_{it} . \qquad [10]$$

In models [9] and [10], $\lambda_{main}(t)$ is the entry rate of the main population and $\lambda_i(t)$ is the entry rate of the i:th sub-population. $N_{main,t-1}$, $N_{cl,i,t-1}$, and $N_{i,t-1}$ are main population density, cluster density, and sub-population density, respectively, for the i:th sub-population. All density variables are delayed for one year to avoid problems of simultaneity. $T_{i,t}$ is the age of the i:th sub-population at time *t*. The period effects and other covariates are summarized in vectors p_t and z_t, respectively. The unobserved parameters to be estimated are α_1, α_2, β_1, β_2, γ_1, γ_2, δ, π', and ξ'. For the stochastic error term ε_{it}, $\exp(\varepsilon_{it}) \sim \Gamma[1, \alpha]$ where α can be estimated directly from the data and captures overdispersion. The models were estimated by using the fixed effects mode of the STATA 9 built-in routine XTNBREG.

6 Results

To test hypotheses H1a, a standard negative binomial regression model was first estimated for the entry rate of biotechnology firms at the main population level. The estimates obtained from this model are presented in the first column of Table 9 (model 1). The results show statistically significant ($p < 0.05$) density-dependent effects of both legitimation and competition (N_{main} and N^2_{main}, respectively) on the rate of entry of biotechnology forms to the main population. Thus, hypothesis H1a is confirmed. This finding shows (again) the strong explanatory power of the standard density-dependence theory (Hannan, 1986).

However, it seems that the basic single-population density-dependence model applies best on relatively high levels of aggregation. This is shown by the results from models 2.1 through 2.11 in Table 9. In these models, each sub-population was modeled as an individual population, separate from each other and the main population[16]. The standard single-population density-dependence model was used. From Table 9, the estimates for both N_i and N^2_i are significant and to the right direction only for one sub-population, Pharmaceutical/therapeutic (model 2.10), which is also the largest individual sub-population. Also the Diagnostics sub-population (model 2.6) has the coefficients of density into the right direction, but only the squared term (i.e. competition) is significant. For Biomaterials (model 2.4), the linear coefficient is significant at $p < 0.10$, showing a weak legitimation effect. Both coefficients are significant for Environment (model 2.7), but into the wrong direction. For the rest of the sub-populations, both density coefficients are insignificant and only partially in the

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[16] The sub-population Devices and Equipment was excluded from this analysis, because the regression model did not converge for this sub-population.

right direction. Thus, Hypothesis H1b receives only very limited support, and cannot be confirmed.

Table 9: Single Population Negative Bionomial Models

(Sub-)population/ Variables	(1) Main population	(2.1) Agro-biotech	(2.2) Bioenergy	(2.3) Bio-informatics	(2.4) Bio-materials	(2.5) Bio-production	(2.6) Diagnost.	(2.7) Environ-ment	(2.8) Enzymes	(2.9) Food and feed	(2.10) Pharma./ therap.	(2.11) R&D service
Constant	2.545**	–0.481	6.157	–17.500	4.416	2.717	1.020	–6.359†	1.636	–1.609	1.550	0.392
	(0.807)	(2.722)	(5.848)	(3,648.533)	(5.511)	(2.393)	(2.021)	(3.882)	(2.784)	(1.942)	(1.710)	(2.980)
N_i		5.960	5.756	30.219	7.769†	6.330	3.927	–14.240†	–2.711	–0.640	7.806†	2.378
		(10.582)	(9.040)	(28.794)	(6.011)	(6.526)	(4.823)	(8.766)	(5.837)	(4.035)	(5.840)	(6.230)
N^2_i		–5.758	–3.741	–27.560	–7.580	–5.129	–5.118†	14.620*	2.357	–1.594	–8.005*	–2.626
		(8.277)	(8.180)	(21.496)	(6.264)	(5.075)	(3.542)	(7.735)	(5.177)	(3.004)	(4.552)	(3.541)
N_{main}	0.016*											
	(0.008)											
N^2_{main} / 1000	–0.054*											
	(0.025)											
$Entries_{t-1}$	0.065*	–2.068**	–36.073	–2.450	–0.441	–0.256	–0.120	–0.667	–0.457	0.318	–0.084	–0.286
	(0.037)	(0.868)	(9,024.602)	(2.703)	(0.554)	(0.341)	(0.171)	(0.723)	(0.573)	(0.300)	(0.158)	(0.558)
$Entries^2_{t-1}$	–0.002**	0.752*	17.744	0.505	0.037	0.059	0.000	0.078	0.027	–0.041	–0.001	0.024
	(0.001)	(0.359)	(4,512.301)	(1.010)	(0.137)	(0.076)	(0.014)	(0.208)	(0.153)	(0.050)	(0.011)	(0.065)
GDP	–0.017*	0.002	–0.069	0.004	–0.053	–0.039†	–0.020	0.070*	–0.017	0.009	–0.011	–0.018
	(0.009)	(0.034)	(0.062)	(0.100)	(0.049)	(0.029)	(0.021)	(0.042)	(0.031)	(0.020)	(0.020)	(0.035)
Recession 1 (1976–77)	0.273	–0.581				0.499	1.406			0.154	–0.409	–13.865
	(0.414)	(1.472)				(0.968)	(1.126)			(1.423)	(0.714)	(1,208.451)
Recession 2 (1990–93)	–0.358*	–1.169†	–18.845	16.995	0.205	–0.986†	–0.980*	0.532	–0.481	–0.234	0.731†	–0.351
	(0.210)	(0.881)	(5,870.853)	(3,648.515)	(0.753)	(0.733)	(0.524)	(0.755)	(0.801)	(0.606)	(0.493)	(0.857)
P1 (1978–)	0.200	–1.074				0.006	0.919		–0.616	0.603	–1.002	0.405
	(0.445)	(1.659)				(1.456)	(1.176)		(1.406)	(1.179)	(0.941)	(1.240)
P2 (1988–)	0.630*	0.767	0.372		1.316	1.303†	1.784**	1.340	2.791*	1.110†	0.087	1.313†
	(0.333)	(1.565)	(1.644)		(1.390)	(0.859)	(0.734)	(1.538)	(1.230)	(0.803)	(0.678)	(0.988)
P3 (1995–)	0.613*	–0.510	0.722	12.996	1.438	0.177	0.946†	–2.756*	0.215	0.884	1.707**	1.803*
	(0.297)	(0.949)	(2.590)	(3,648.515)	(1.314)	(0.952)	(0.659)	(1.382)	(0.994)	(0.734)	(0.658)	(0.818)
P4 (2001–)	0.735**	0.407	1.617	–0.826	1.952*	1.538*	1.380**	–3.493*	–1.573†	–0.407	1.359**	1.088*
	(0.313)	(2.074)	(1.878)	(2.012)	(0.895)	(0.885)	(0.499)	(1.706)	(1.178)	(0.708)	(0.558)	(0.639)
Observations	34	34	27	14	25	34	33	28	31	33	34	34
Log-likelihood	–88.44	–33.35	–15.97	–11.58	–27.49	–44.47	–53.06	–30.05	–31.78	–46.80	–58.42	–38.35

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, one-tailed tests. Standard errors in parentheses. Period effects are set to one during the indicated period and zero otherwise.

The above findings indicate that different density-dependent mechanisms operate within the main population that affect the entry of firms into the individual sub-populations. The remaining hypotheses assume that the heterogeneous main population has an underlying systemic structure which causes density-dependent effects to sub-population entry beyond the boundaries of the individual sub-populations.

Table 10 below presents the estimates obtained from three fixed-effects negative binomial regression models that take the systemic structure into account (models 13 - 15). The simple systemic structure illustrated in Figure 1 above is used as the basis for these models. Thus, the entry data from all twelve sub-populations is pooled together into the same entry variable. Model 3 estimates the effect of sub-population density on sub-population entry rates, ignoring the effects of main population density. The estimates show statistically significant legitimizing and competitive effects in the predicted direction (N_i and N^2_i, respectively; both effects are significant at $p < 0.01$). This indicates that hypothesis H1b would hold if the underlying systemic structure of the main population was taken into account. Put differently, the results from model 3 show that there is something common in the way that the sub-population level processes of density-dependence – as well as the effects of the common environment – operate within these particular sub-populations. The results from model 3 provide also support for hypothesis H2b, even though the whole system is not accounted for.

Model 4 proceeds to estimate the direct effect of main population density on sub-population entry without the effect of sub-population density. The results indicate that when the densities of the individual sub-populations are ignored, the main population shows both legitimizing and competitive effects on sub-population entry that are both significant at the level $p < 0.01$. This result provides a final confirmation for the assumption that the sub-populations form a systemic structure with hierarchical relationships to the main population, and that density-dependent effects operate across the internal boundaries of such a system. Note, however, that replacing sub-population density with main population density decreases the fit of the model significantly, as shown by the likelihood-ratio and log-likelihood indicators.

Model 5 takes simultaneously into account the full structure of the system and the density-dependent effects of legitimation and competition from different hierarchical levels of the underlying heterogeneous population. It shows the combined effects of main population density and sub-population density on sub-population entry. The likelihood-ratio and log-likelihood tests show statistically significant improvement in model fit in comparison to model 3 and especially to model 4.

The most important finding from model 5 is that when the whole systemic structure of the heterogeneous main population is taken into account, main population density (N^2_{main}) no longer shows an effect of density-dependent competition. However, a legitimation effect still remains for the main population density, significant at $p < 0.10$. In addition, for sub-population density continues to have effects of legitimation and competition, both of which significant at the level $p < 0.01$. These results confirm hypothesis H2a and H2b.

Table 10: Fixed-Effects Negative Binomial Regression Models of Sub-Population Entry

Variables	(3) Sub-pop. entry	(4) Sub-pop. entry	(5) Sub-pop. Entry
Constant	16.306	14.001	14.916
	(1,074.801)	(496.885)	(383.113)
N_i	3.664**		2.834**
	(1.077)		(1.183)
N^2_i	–3.972**		–3.431**
	(0.890)		(0.984)
N_{main}		0.022**	0.013†
		(0.007)	(0.008)
N^2_{main} / 1000		–0.067**	–0.028
		(0.022)	(0.024)
$Entries_{t-1}$	0.094†	0.112*	0.097*
	(0.058)	(0.055)	(0.058)
$Entries^2_{t-1}$	–0.012*	–0.013**	–0.012**
	(0.005)	(0.005)	(0.005)
GDP	–0.016**	–0.019**	–0.019**
	(0.006)	(0.007)	(0.007)
Recession 1 (1976–77)	0.245	0.189	0.169
	(0.368)	(0.371)	(0.371)
Recession 2 (1990–93)	–0.391*	–0.468**	–0.454**
	(0.181)	(0.183)	(0.183)
P1 (1978–)	0.191	–0.128	–0.140
	(0.328)	(0.412)	(0.411)
P2 (1988–)	0.948**	0.592*	0.623*
	(0.221)	(0.299)	(0.299)
P3 (1995–)	0.669**	0.456*	0.458*
	(0.189)	(0.243)	(0.244)
P4 (2001–)	0.755**	0.847**	0.847**
	(0.214)	(0.268)	(0.265)
Observations	361	361	361
Number of sub-populations	12	12	12
Log-likelihood	–462.14	–468.40	–460.65

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, one-tailed tests. Standard errors in parentheses.
Period effects are set to one during the indicated period and zero otherwise.

The relative strengths of the density-dependent effects of legitimation and competition cannot be directly observed from the estimated coefficients. Instead, it has become customary to plot graphical representations of the relationship between density and entry rate (Cattani *et al.*, 2003; Dobrev, 2001; Greve, 2002a; Hannan *et al.*, 1984; Wezel, 2005). Figure 10 and Figure 11 below show the multipliers of the sub-population entry rate for sub-population density (model 3) and main population density (model 4), respectively. In both cases, the effect of density on entry follows the shape of an inverted U, and the maximum entry rate multipliers occur below the maximum density level.

Figure 10 (model 3, sub-population density only) shows clearly the effects of both legitimation and competition. Legitimation shows as the initial rise in the entry rate multiplier with density. The maximum effect on entry occurs at the sub-population density level 0.46, slightly below the midpoint of the standardized scale [0,1]. At the maximum point, sub-population density has more than a doubling effect on sub-population entry (multiplier value 2.33). However, as sub-population density increases further, competition overruns legitimation and turns the entry-boosting effect gradually into a diminishing effect. The entry rate multiplier at maximum sub-population density is 0.73, thus suggesting a relatively strong competitive effect. In other words, when sub-populations become well populated (i.e. close to their maximum density), effects of diffuse competition make the rate of entry approximately 25% lower than for the first entrant at zero density – other factors controlled.

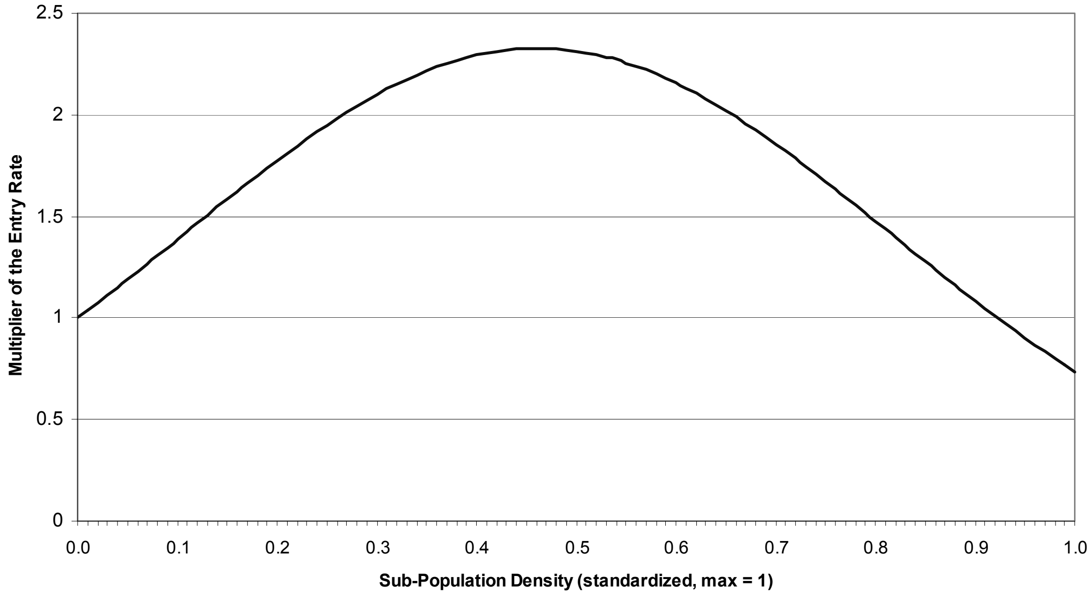

Figure 10: The Effect of Sub-Population Density on Sub-Population Entry (Model 3)

In Figure 11 (model 4, main population density only), the maximum effect of main population density on sub-population entry occurs at N_{main} = 162, slightly above the median value of the scale. At this point, the multiplier value is 5.87, showing a strong boosting effect on entry rate. The maximum value of the multiplier is clearly higher than for sub-population density in Figure 10. Although both legitimation and competitive effects are visible in Figure 11, the multiplier at maximum density N_{main} = 267 is almost three times higher than the multiplier at zero density. This means that, at its maximum, the main population density still has a positive effect on sub-population entry. The findings from Figure 10 and Figure 11 can be summarized as follows. Ignoring the effect of sub-population density, main population density has a strong legitimizing and a less strong competitive effect on sub-population entry. Ignoring the effect of main population density, sub-population density has a moderate legitimation and a relatively strong competitive effect on sub-population entry. In models 13 and 14, main population density has a clearly stronger positive effect on sub-population entry than sub-population density. This provides partial support for hypothesis H2c, even though the whole structure of the system is not taken into account simultaneously.

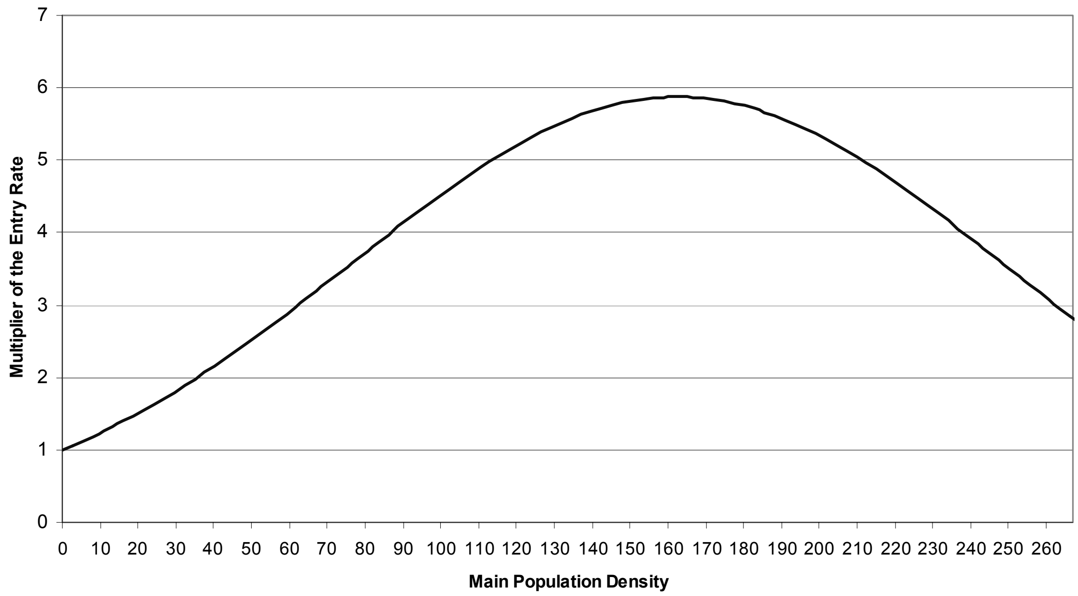

Figure 11: The Effect of Main Population Density on Sub-Population Entry (Model 4)

Figure 12 shows the entry rate multipliers of main and sub-population densities obtained from model 5. For comparability, also the coefficient for the competitive effect of the main population (N^2_{main}) is included in the graph – even though it is not statistically significant. Figure 12 shows that, as predicted by hypothesis H2a, main population density has mainly a legitimizing (positive and increasing) effect on entry. The entry rate multiplier increases strongly with main population density, reaching its maximum value 4.20 at the density level 226 (0.84 on the standardized density scale). The subsequent competitive effect is minimal and, as noted earlier, not statistically significant.

Sub-population density, on the other hand, has first a legitimation effect that slightly boosts entry (maximum multiplier 1.80 occurs at the standardized density level 0.41). However, as density rises, this soon turns into competitive effect that decreases the entry rate. At the maximum sub-population density (1 in the standardized scale), the multiplier of the entry rate is 0.55. Clearly – in line with hypotheses H2a and H2b, ecological competition occurs mainly at the sub-population level, whereas the effects of legitimation originate also from the level of the main population.

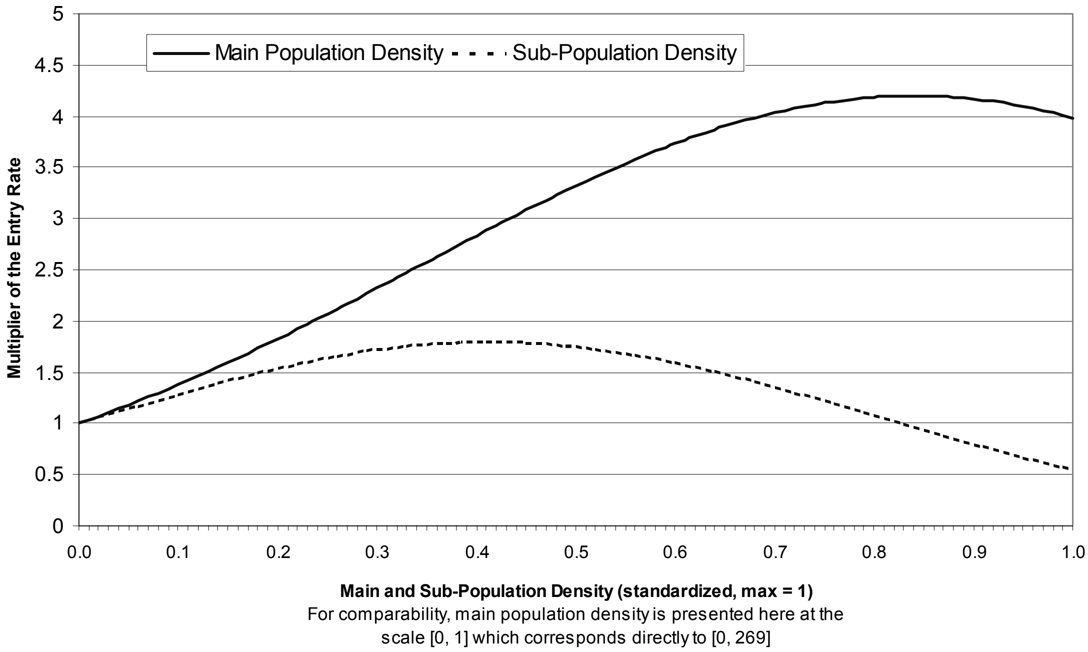

Figure 12: The Effect of Main and Sub-Population Density on Entry (Model 5)

Figure 12 also finally confirms hypothesis H2c which suggests that main population density has a stronger legitimizing effect than sub-population density. This can be directly observed from the graph, where the effect of main population density is higher than the effect of sub-population density throughout the observed scales. As noted earlier, at its best, the legitimation effects of main population density can boost sub-population entry rates more than four-fold. On the other hand, sub-population density can barely reach an effect of increasing sub-population entry rates two-fold.

To summarize and visualize the combined effect of main and sub-population density in the simple systems structure, a three-dimensional surface is plotted in Figure 13 based on the coefficients obtained from model 5. Interestingly, sub-populations that start off at a stage when the main population has already grown to a considerable size are able to get a strong boost of legitimation to their entry rates, compared to those that start at small main population density. At the peak of the surface, the entry rate multiplier is over 7.5 times higher than at the origin where both densities are zero. In contrast, sub-population density captures a rather strong competitive effect when getting closer to its maximum. At maximum main population density, increasing sub-population density may reduce the entry rate multiplier to less than one third of its peak.

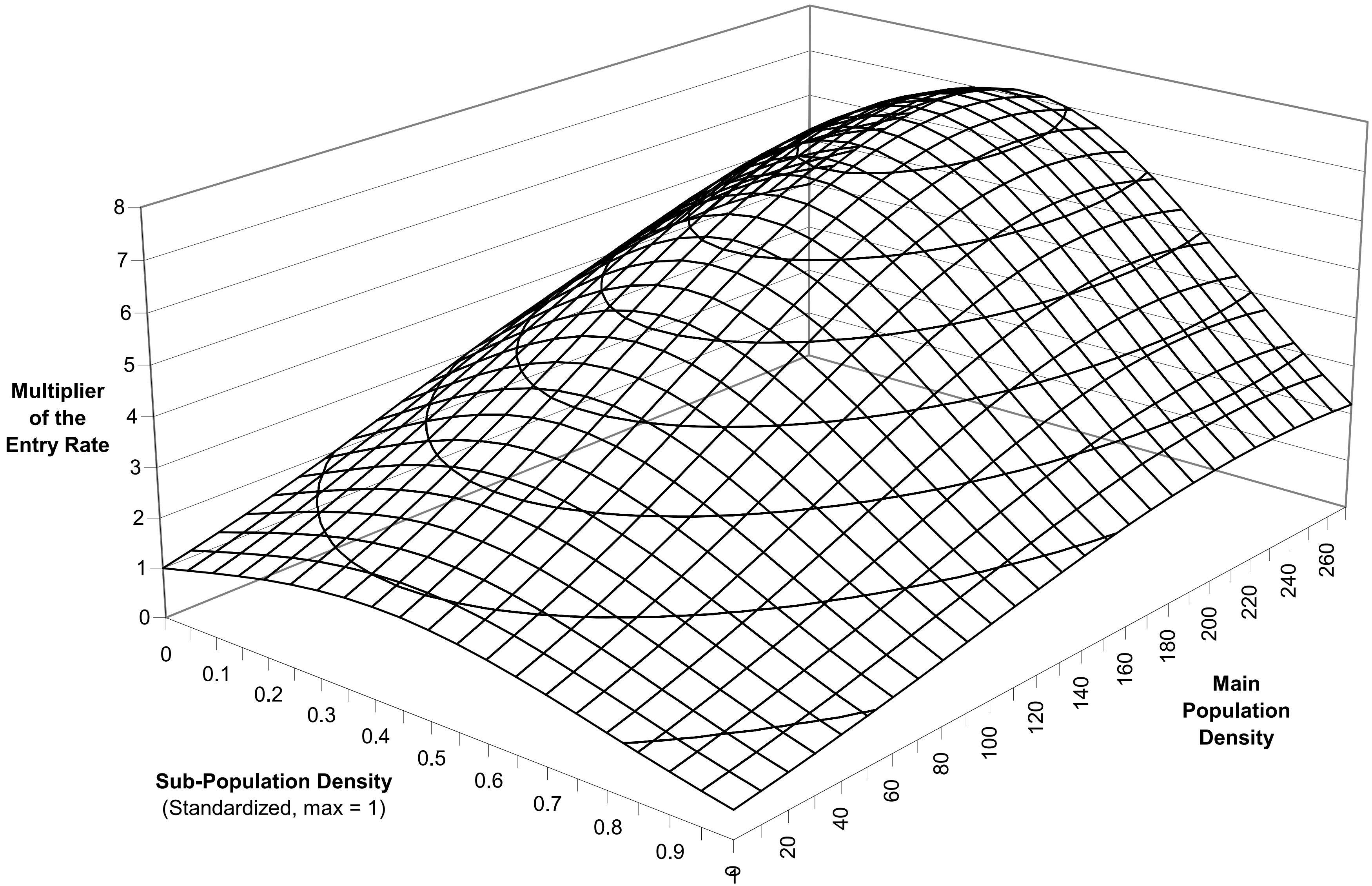

Figure 13: Combined Effect of Main and Sub-population Density (Model 5)

Table 11 below presents four additional models that are based on a more complex population structure including the cluster level between the main population level and the sub-population level (refer to Figure 9 above). Again, fixed-effects negative binomial models were used, but three dummies were added to control for fixed effects also in the cluster level (estimates not shown in Table 11). The same models were tested also without the cluster dummies, and the effects remained effectively the same. The models were also tested with the Devices & Equipment cluster omitted, again yielding effectively the same results. The rationale of this test was that the Devices and Equpment cluster is a special case where the cluster includes only one sub-population, thus making the cluster and the sub-population densities equal. This could have again caused distortion to the estimates.

Model 6 begins by testing the effect of cluster density on sub-population entry in isolation from the other density variables. The results from model 6 show significant ($p < 0.01$) legitimation and competition effects for cluster density, providing initial support for hypothesis H3a. Model 7 proceeds to add the effects from sub-population density. This time, only the effect of competition is significant ($p < 0.10$) for sub-population density. This finding does not only bring additional support for hypothesis H3a, but also partially disconfirms hypothesis H2b. With the additional cluster layer in the hierarchical structure of the population, it seems that the individual sub-populations have no significant effect of legitimation at all. Nonetheless, the process of diffuse ecological competition would be clearly present at the sub-population level.

Model 8 drops sub-population density and adds main population density together with cluster density. Interestingly, now that cluster density is included in the model, the main population has no significant effect at all. Put differently, in model 8, all effects of legitimation and competition are contained to the cluster level. This finding shows again support for hypothesis H3a, but at the same time disconfirms hypothesis H2a. Finally, model 9 combines density variables from all three levels. This time, no new effects appear. Rather, model 9 essentially replicates the effects from the three previous models. Main population density has no effect, cluster density causes both legitimation and competition, and sub-population density only competition. Thus hypothesis H3a is supported, while hypotheses H2a and H2b receive total and partial disconfirmation, respectively.

Table 11: Models of Sub-Population Entry with Cluster Density

Variables	(6) Sub-pop. entry	(7) Sub-pop. entry	(8) Sub-pop. Entry	(9) Sub-pop. entry
Constant	1.821†	1.942†	1.851†	2.018†
	(1.350)	(1.433)	(1.409)	(1.513)
N_i		0.479		0.455
		(1.474)		(1.475)
N^2_i		–1.846†		–1.798†
		(1.204)		(1.210)
N_{cl}	6.826**	6.334**	6.882**	6.489**
	(1.677)	(2.134)	(1.911)	(2.368)
N^2_{cl}	–6.015**	–4.237**	–6.319**	–4.559**
	(1.249)	(1.632)	(1.590)	(1.937)
N_{main}			0.005	0.001
			(0.015)	(0.015)
N^2_{main} / 1000			–0.000	0.004
			(0.037)	(0.037)
T_i	0.002	–0.001	–0.034	–0.016
	(0.038)	(0.037)	(0.069)	(0.069)
$Entries_{t-1}$	0.081†	0.093†	0.075†	0.090†
	(0.058)	(0.059)	(0.057)	(0.059)
$Entries^2_{t-1}$	–0.012**	–0.013**	–0.012**	–0.013**
	(0.005)	(0.005)	(0.005)	(0.005)
GDP	–0.018**	–0.018**	–0.018*	–0.019*
	(0.007)	(0.007)	(0.008)	(0.008)
Recession 1 (1976–77)	0.154	0.166	0.190	0.184
	(0.375)	(0.374)	(0.376)	(0.376)
Recession 2 (1990–93)	–0.446**	–0.456**	–0.452**	–0.456**
	(0.188)	(0.184)	(0.185)	(0.184)
P1 (1978–)	–0.242	–0.203	–0.184	–0.153
	(0.389)	(0.388)	(0.425)	(0.425)
P2 (1988–)	0.605*	0.613*	0.604*	0.627*
	(0.267)	(0.265)	(0.305)	(0.305)
P3 (1995–)	0.514**	0.473*	0.405†	0.419†
	(0.220)	(0.217)	(0.256)	(0.256)
P4 (2001–)	0.936**	0.959**	0.896**	0.919**
	(0.235)	(0.234)	(0.275)	(0.274)
Healthcare[1]	14.944	15.486	14.925	15.017
	(494.042)	(838.800)	(638.479)	(1,037.662)
Industrial Biotech[1]	2.449	12.149	10.615	12.223
	(7.844)	(1,090.419)	(866.498)	(903.023)
Agro-Food-Feed[1]	14.318	14.496	14.202	14.406
	(1,789.619)	(1,020.345)	(1,242.194)	(1,494.257)

Observations	361	361	361	361
Number of sub-populations	12	12	12	12
Log-likelihood	–459.99	–456.60	–459.67	–456.49

† $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, one-tailed tests. Standard errors in parentheses.
[1] Three dummies were used for controlling fixed effects at cluster level.
Period effects are set to one during the indicated period and zero otherwise.

To examine the strengths of the effects, multipliers of the entry rate are again plotted graphically. Fist, Figure 14 plots the effects of cluster density isolated from other levels of density (model 6). The effects of legitimation and competition are clearly visible, with a maximum multiplier 6.93 occurring at the standardized cluster density 0.57. It can be noted that legitimation clearly dominates over competition, since the multiplier never gets below zero. At maximum density, the multiplier is still above 2, thus having a positive effect on sub-population entry.

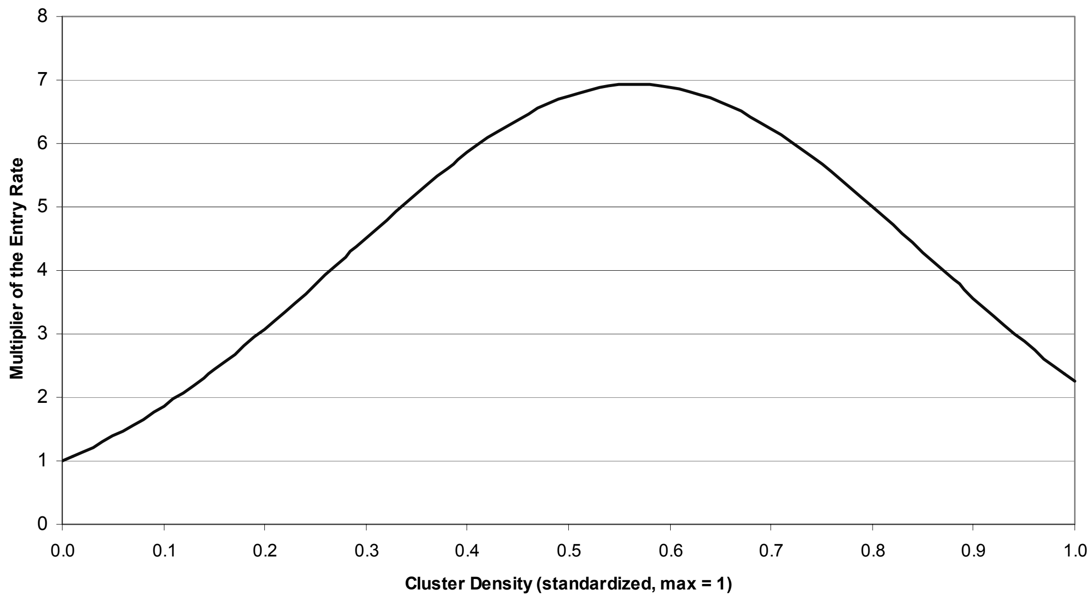

Figure 14: The Effect of Cluster Density on Sub-Population Entry (Model 6)

Figure 15 visualizes the results of model 7, i.e. the simultaneous effects of cluster and sub-population density. A logarithmic scale is used to make the effects more comparable. Even though the estimates for both the linear and squared versions of cluster density were statistically significant, Figure 15 shows that the effect of density-dependent competition is very small for cluster density. Instead, cluster density has a strong effect of legitimation on sub-population entry. At the highest point, the multiplier by cluster density is as high as 10.67. At the same time, sub-population has virtually only a competitive effect, which is rather strong. At maximum sub-population density, the multiplier of entry rate is as low as 0.25. Thus, according to this model, the increase in the number of firms representing the same sub-form can have a major negative impact in the rate of entry of new firms.

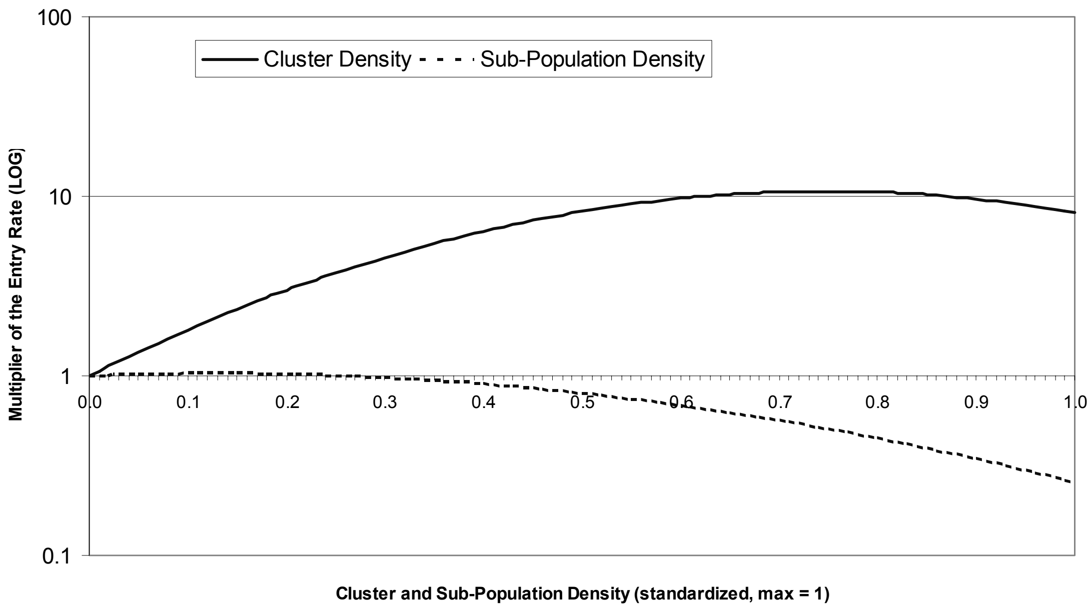

Figure 15: The Effects of Cluster and Sub-Population Density on Entry (model 7)

Similar plots were also drawn from the coefficients of model 9, but the resulting graphs were essentially identical to those in Figure 15. This is expected since main population density has very little effect in model 9. Thus, Figure 15 also confirms hypotheses H3b and H3c. Cluster density causes stronger effects of legitimation, while sub-population density causes stronger effects of competition. Finally, Figure 16 shows the combined effects of cluster and sub-population density on a three-dimensional chart. From Figure 16, the most favorable combination for entry is when the cluster is already rather well established, but very few other firms representing the same sub-form still exist. Bioinformatics illustrates such a case. The first bioinformatics firm entered in 1993, while the Healthcare Biotechnology cluster was established already 20 years earlier. Not surprisingly, the Bioinformatics cluster has grown relatively rapidly after the establishment of the 1st firm. On the other hand, the worst combination for entry would be a situation where a single sub-population has been relatively well established, but no other related sub-populations have so far entered.

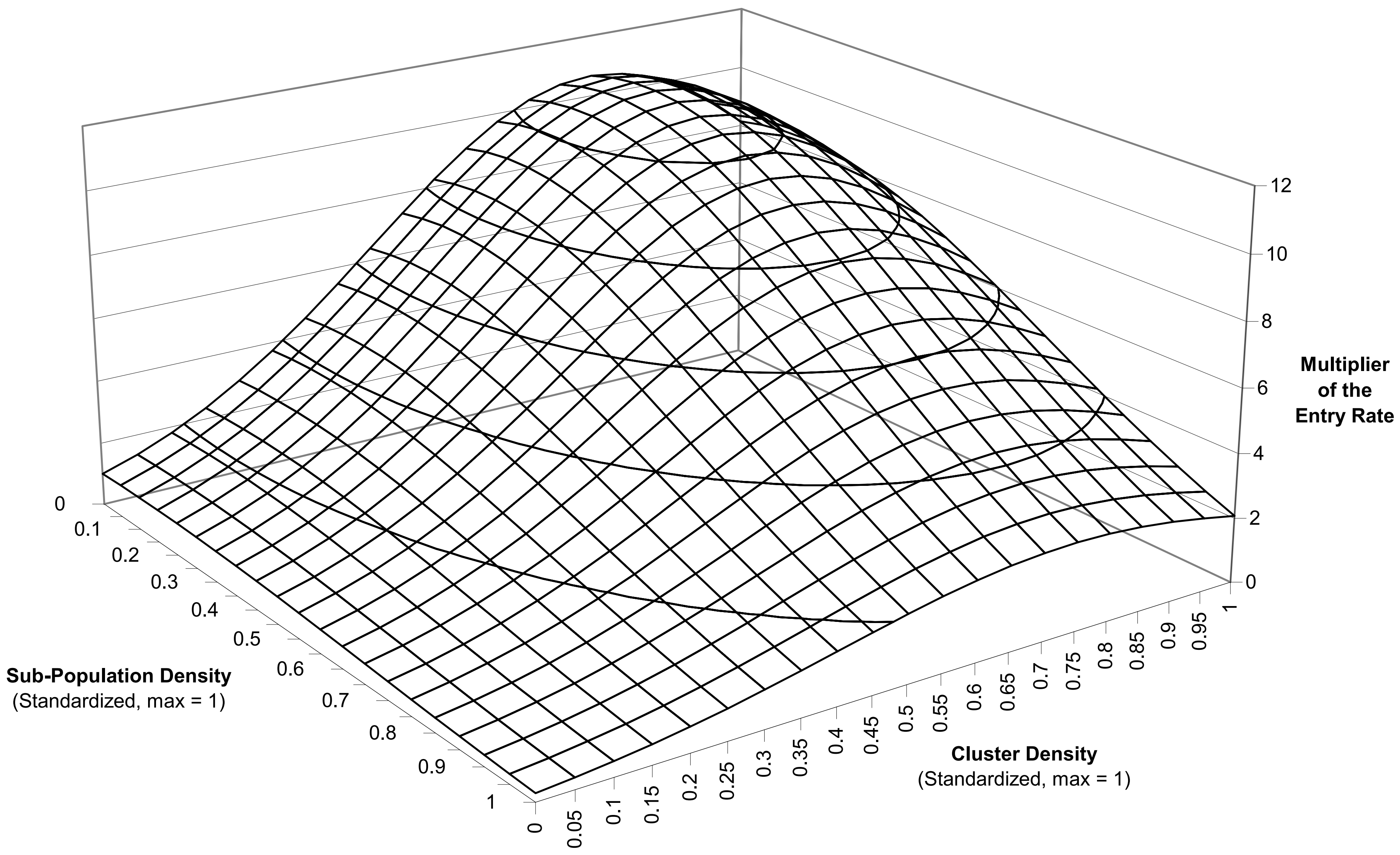

Figure 16: Combined Effects of Cluster and Sub-Population Density (model 7)

7 Discussion and Conclusion

One of the fundamental research questions in organizational ecology has been “why are there so many kinds of organizations” (Hannan *et al.*, 1977). Besides the mechanisms creating organizational diversity in the first place, great interest also falls on how such organizational variation affects patterns of mutualism and competition in organizational populations (Baum *et al.*, 1994a). The present study was motivated by developing the ecological approach further in understanding how organizational entry unfolds in populations with high internal heterogeneity caused by the complexity of the underlying organizational form. As noted earlier, it can be observed that a majority of pre-existing empirical research in organizational ecology has focused on simple organizational forms defined by product-markets. Moreover, the concept of organizational form has not always been robustly applied in defining empirical populations.

However, populations are often heterogeneous (Cattani *et al.*, 2003), and a special type of heterogeneity is related to the complexity of organizational forms. To date, few research efforts have been directed at studying how mutualistic and competitive forces shape organizational entry in heterogeneous populations characterized by complex organizational forms. In line with existing theory and research, a systems approach was chosen to analytically approach form complexity and thus capture related population heterogeneity. The idea is to understand complex organizational forms in terms of the underlying, nested sub-forms that are less complex. In the simplest case, two or more simpler sub-forms are hierarchically nested under a single complex main form. A more complex structure incorporates a cluster level whose hierarchical position falls between the main form and the individual sub-forms. Hypotheses were derived regarding density-dependent effects of legitimation and competition on organizational entry in a heterogeneous population characterized by such systems of organizational forms.

The hypotheses were empirically validated with data on the biotechnology industry in Finland in the period 1973-2006. The technology-driven main form – modern biotechnology – is complex and several audiences collectively associate a heterogeneous set of organizations to it. These organizations operate on diverse product markets with a multitude of business strategies. Twelve sub-forms and related sub-populations can be identified from the Finnish biotechnology industry. Each of them holds a less complex organizational form that is more readily defined by a specific product-market.

The results of the analysis can be summarized as follows. In the simple two-level system, main population density has a strong density-dependent effect of legitimation on sub-population entry, whereas the effects of ecological competition are almost completely contained within the individual sub-populations. When the cluster level is incorporated to the analysis, main population density is left without effect. Legitimation takes place almost completely on the cluster level, whereas competition is still captured into the sub-population level.

Two key findings can be inferred from the above results. First, the systemic structure of the population matters, i.e. entry to the individual sub-units is affected by the other parts and levels of the system. When the individual sub-populations are observed in isolation from the rest of the system, the density-dependent effects are weak and work in ambiguous directions. The baseline density-dependence model seems to work adequately on the main population level, but the systems approach is clearly more powerful in capturing the effects stemming from the underlying diversity, compared to an approach based on a single uniform organizational form. The different units and levels have clear communal interdependencies, and exert mutualistic and competitive forces on one another. Second, the results show that legitimation generally operates on a broader level than competition. In all models, competition is contained to the sub-population level. Legitimation operates either on the main population or cluster level. Similar results have been produced in a number of earlier studies in the geographical context (Cattani *et al.*, 2003; Hannan, 1997; Hannan *et al.*, 1995c).

The following sections elaborate the implications of the present study on organization theory in general, the field of organizational ecology, density-dependence theory, other literatures, and methodology. Thereafter the limitations of the study and questions left open for future research are discussed. This is followed by implications to institutional decision-making and management practice. Finally, conclusions are drawn regarding the general contribution of the study.

7.1 General Implications to Organization Theory

The present study contributes to organization theory by shedding additional light on (i) the mechanisms creating organizational diversity, (ii) how such diversity is structured, and (iii) what implications such diversity has on the large-scale mutualistic and competitive interdependencies between organizations. In particular, the study brings additional understanding on the levels at which mutualistic and competitive forces operate.

First, several mechanisms work together to create and maintain organizational diversity. The entry of organizations is a key process through which large-scale organizational change and transformation generally occur (Aldrich, 1999; Hannan *et al.*, 1989). Organizations are highly dependent on their social and material environments (Aldrich, 1979; Meyer *et al.*, 1983; Pfeffer *et al.*, 1978), and such environments are generally diverse and fast changing (Chandler, 1990; Hannan *et al.*, 1977). The principle of isomorphism warrants that the diversity of organizations and organizational properties mirror the contemporaneous diversity of environments (Hawley, 1968; Stinchcombe, 1965). The overall organizational landscape is generally discontinuous, and organizational populations are distributed along a finite number of organizational forms. On a more concrete level, organizational diversity is created and maintained by the process by which audiences – i.e. sets of powerful social actors – screen individual organizations' conformity to specific rule-like codes that are attached to the collective identities of forms (Hsu *et al.*, 2005; Polos *et al.*, 2002). Conformity to such sets of codes has a positive effect on how organizations are valued, and vice versa. Some forms are such that a relatively high number of distinct audiences associate a diverse set of codes to a specific, complex form (Hsu *et al.*, 2005; Zuckerman *et al.*, 2003). For such forms, a diverse set of organizations is able to pass the code-conformity-test by the related but disparate audiences, thus creating heterogeneous populations. This is a mechanism that creates diversity within individual organizational populations.

Second, classic work in both human ecology (Hawley, 1950) and organizational ecology (Hannan *et al.*, 1977) have stressed the systemic nature of social structures. The open-systems perspective to organizations is also central in organization theory (Scott, 2003: 82-84). Indeed, organizational phenomena and evolutionary processes can be studied at various levels of analysis, ranging from individual people through intraorganizational units, organizations, and organizational populations event to organizational communities (Amburgey *et al.*, 1996; Hannan *et al.*, 1977). These levels form social systems that have hierarchical structures with nested levels and related, interdependent sub-units. Also identities, forms, and populations can be hierarchically nested (Carroll *et al.*, 2000a: 69, 74), thus forming systems with hierarchical or other kinds of structures (Carroll *et al.*, 2000a: 76-78; McKendrick *et al.*, 2001). The present study shows how complex organizational forms can be systems of hierarchically nested sub-forms, thus generating organizational populations with salient sub-populations mirroring the internal structure of the complex form.

Finally, it is proposed and confirmed that such systemic structures of organizational diversity have impacts on the large-scale mutualistic and competitive interrelationships between organizations. Interdependencies that generate legitimation are more easily transmitted across internal system boundaries than relationships driving ecological competition of resources from the environment.

7.2 Extensions and Contrasts with Existing Population Ecology Literature

Despite its centrality in defining populations, the concept of organizational form has not always been robustly applied in specifying empirical populations (cf. Hsu *et al.*, 2005). As a consequence, much research on organizational ecology has focused on simple organizational forms, often defined inadequately by pre-existing industrial categories or general product-markets. As Hsu and Hannan (2005) note, this is not necessarily how audiences truly perceive organizational forms and populations. A reason for the lack of use of the concept of organizational form may be that its theoretical groundings have not been solid enough (cf. McKendrick *et al.*, 2003; Romanelli, 1991). Thus recent literature has suggested a revised, identity-based approach to organizational forms (Polos *et al.*, 2002) that allows also a robust conceptual base for distinguishing between simple and complex organizational forms (Hsu *et al.*, 2005; Zuckerman *et al.*, 2003).

Having identified the general abundance of studies with simple empirical populations, the present study was set forth by asking whether and how the ecological approach could be applicable to complex organizational forms, thus capturing effects caused by the resulting population heterogeneity. This objective is well in line with general aim of organizational ecology to build models of population dynamics that are generalizable across various empirical contexts and historical time. This paradigmatic stance is often cited as one of the strengths of the ecological approach (Baum, 1996; Carroll *et al.*, 1989c, 2000a; Hannan, 1997; Hannan *et al.*, 1995b; Hannan *et al.*, 1989; Singh, 1993). The density-dependence theory in its basic form (Hannan, 1986) and the vast amount of supporting empirical research from diverse industrial settings show that building such theory and models is generally possible.

The results of the present study show that the identity approach in general, and form complexity in particular, are relevant bases for conceptualizing and dimensionalizing organizational forms and therefore empirical populations. It was shown that the Finnish biotechnology industry has a complex organizational form with a broadly defined main identity and several underlying sub-identities. A multitude of different audiences exist with varying levels of power to affect the viability of the biotechnology firms, such as public institutions, industry associations, financiers, educated labor with differentiated skills, and, most importantly, customers from several distinct product-markets. Each audience associates a differentiated (but overlapping) set of identity codes to the main and sub-identities. The individual sub-identities also have differing levels of importance to each audience. The relative importance varies most across those audiences that are formed by the customer bases for each of the underlying product-markets (e.g. pharmaceuticals vs. industrial enzymes).

Besides conceptualizing form complexity, the identity approach also provides a plausible theoretical platform for studying complex forms through a systems approach (McKendrick *et al.*, 2001). In other words, the identity approach enables the operationalization of complex forms into meaningful, researchable systems with hierarchically nested internal structures. A systems approach as such is not new in organizational ecology. Already in his seminal work on human ecology, Hawley (1950) has suggested that ecological systems can be studied in terms of their more elemental systems. Thereafter, a systems approach has been used to study e.g. the evolution of technologically complementary and substitutive telecommunications firms (Barnett, 1990). Similarly, a systems approach has been used in studying the geographical clustering of sub-populations (Cattani *et al.*, 2003; Greve, 2002a; Hannan, 1997; Hannan *et al.*, 1995c; Lomi, 1995a, 2000; Wezel, 2005). The present study has demonstrated that a systems approach is able to bring additional precision to the predictions of ecological theory also in the context of complex organizational forms. The study also shows that the systemic structure of a complex form is sharply reflected in related empirical populations and has effects on the density-dependent dynamics within the populations.

The present study also holds several linkages to the studies of community ecology (Astley, 1985; Dobrev *et al.*, 2006; Ruef, 2000). Just as community ecology emphasizes the symbiotic relationships between separate populations that occupy non-overlapping niches (Aldrich, 1999: ch. 11; Hawley, 1950: 40-41), the current study finds that individual sub-populations have positive interrelationships to each other. Such effects can even foster the emergence of new sub-populations, as exemplified by the bioinformatics sector within the Finnish biotechnology industry (cf. Ruef, 2000).

7.3 Extensions and Implications for Density-Dependence Literature

Pre-existing formulations of density-dependence have not explicitly addressed the question of how density-dependent processes of legitimation and competition operate in heterogeneous populations characterized by complex organizational forms. Additionally, few studies have applied a systems approach to account for the variation of organizational properties within a population. Nonetheless, existing studies of density-dependence have addressed both population heterogeneity and organizational variation, albeit through somewhat different lenses.

The implications of population heterogeneity have been relatively widely investigated in the spatial context. Several pieces of earlier work have studied the ways in which organizations tend to cluster geographically, how the geographical clusters relate to one other and the national population, and what implications such structures have on the density-dependent processes of legitimation and competition and thus organizational entry (e.g. Greve, 2002a; Hannan, 1997; Hannan *et al.*, 1995c; Lomi, 1995b; Wezel, 2005). Often, a simple systemic structure has been adopted with typically two or more geographical sub-populations underlying an overall national population. Although cross-effects between the specific parts of the system have been studied, only a few times has the whole system structure been accounted in its entirety in a single model (e.g. Cattani *et al.*, 2003). Even so, it has been found that also in the context of spatial heterogeneity, legitimation tends to operate more broadly than competition (Hannan *et al.*, 1995c). This supports the findings of the present study, albeit the underlying explanatory mechanisms and their domain are somewhat different. The present study shows that there are internal system boundaries that are less concrete than in the geographical domain. Similar to spatial boundaries, the internal boundaries within complex organizational forms are more permeable for legitimation than competitive effects.

What comes to organizational variation within populations, perhaps the closest earlier approach uses niche theory to theorize how the overlap between organizations' environmental niches affect the processes of organizational entry (Baum *et al.*, 1994a). According to the niche-overlap approach, organizations in a population operate in unique niches within their common environment, and the extent to which organizations' niches overlap has implications on competition and mutualism and thus entry. A context-specific approach has been applied to construct two weighted-density variables – overlap density and non-overlap density – which attempt to separate density-dependent effects originating from overlapping and non-overlapping niches, respectively. In line with the findings of the present study, it has been found that the density originating from overlapping niches creates mainly competitive effects on entry, while non-overlap density promotes mutualism and thus boosts entry (Baum *et al.*, 1994a).

Nevertheless, the niche overlap approach holds several theoretical and methodological differences to the approach advanced in the present study. A conspicuous theoretical departure is that the niche overlap approach focuses solely on variation in organization-specific niches, i.e. the resource combinations that the organizations utilize and are dependent on from their environment. The niche overlap approach ignores the complex structure of collective identities that external audiences enforce to the members of the heterogeneous population, and thus the resulting systemic structure and internal system boundaries. The present study utilizes all three: the identity based approach to complex identities and forms, a systems structure approach, and the way in which organizations are dependent on different sets of resources (i.e. niches) from their environments.

The niche overlap approach also holds several major methodological departures. Typically, a single variable is used to characterize differences in organizations' niches, and this variable is used in weighting densities. A good example is Baum et al's (1994a), work on day care centers where commonality in the organizations' niches is operationalized to a variable that measures the width of the range of ages of the children that the day care centers are willing to enroll. In contrast, the present study has adopted two generic models of hierarchical system structures that may be generalizable to other populations with complex forms. In addition, this study has developed a detailed understanding of the complex structure of the biotechnology form and the historical development of the heterogeneous population of biotechnology firms in Finland. The study has relied on several published and primary sources to understand how audiences categorize firms into the different sub-populations and operationalized this directly into the coding of the empirical data. The coding has been tested and validated by industry experts.

In summary, for density-dependent theory and research, the present study shows that form complexity indeed brings special characteristics to the operation of the density-dependent processes of legitimation and competition. First, it was observed that the densities of the individual sub-populations do not alone have enough power to explain organizational entry when observed in isolation from the rest of the system. However, significant effects could be identified when the systemic structure of the whole heterogeneous population was taken into account. This finding shows that the overall heterogeneous population and its systemic structure have a relatively strong impact on how density-dependent processes of organizational entry operate within heterogeneous populations characterized by complex organizational forms. A second major finding is that legitimation generally operates on a broader level than competition. In the most sophisticated models, effects of legitimation are strongest at the cluster level, while competitive effects are contained to the sub-population level. This is generally supported by studies of spatial heterogeneity (Hannan *et al.*, 1995c) and niche overlap (Baum *et al.*, 1994a).

In effect, the present study enables one to quite precisely determine from which parts of the system legitimation and competitive effects originate from – the main population, cluster, or sub-form level. The results show that the whole main population has a strong legitimizing effect when the cluster level of aggregation is ignored. However, the inclusion of the cluster level shows that the main form is too broadly defined to have strong legitimizing effect. Instead, the cluster level turns out to be the hotspot from which the effects of legitimation originate. Similarly, the results show that competition is always contained within individual sub-populations – something which is in line with ecological theory suggesting that organizations of the same kind compete for resources in their common niches. This study shows that only at the sub-population level the organizations are similar enough to compete from the same resources from the environment. This is how it is supposed to be, since each of the sub-populations represent a distinct product market. And without doubt, demand for products and services is the single most important resource for any commercial organization.

For future theory and research in density-dependence, several implications are suggested. First, to attain increased precision, future research should seek to take into account the organizational variation within a population and thus the level of complexity of the underlying organizational form. Second, a systems approach is often fruitful in capturing such population heterogeneity, and such structures are most likely to affect predictions of density-dependent processes. Third, the identity based approach to organizational forms is a relevant and operational point of departure for conceptualizing and dimensionalizing the complexity of organizational forms. The identity approach is able to bring out such structures and mechanisms that govern especially the institutional side of density-dependent processes. Fourth, at the same time, the theory regarding environments, resources and niches is vital to understand especially the competitive mechanisms of density-dependence. However, the niche approach is highly complementary and even overlapping with the identity approach. Indeed, a key external resource for most modern organizations is the demand for the organizations' outputs. Such demand originates from a customer base that at the same time represents a key audience that defines the external identity of the organizations.

Fifth, formulations of density-dependence should explicitly account for the fact that legitimation tends to generally operate on a broader level than competition in such social structures.

7.4 Implications for Other Literatures

Implications can be drawn also to research in entrepreneurship and strategic management. First, the entry of new organizations is strongly related to entrepreneurial activity and entrepreneurs' decisions to create organizations to pursue for emerging opportunities. However, much of the extant research in entrepreneurship has focused on the internal strengths and weaknesses of organizations in the form of e.g. resources (Barney, 1991; Wernefelt, 1984), knowledge (Grant, 1996; Kogut *et al.*, 1992), social capital (Nahapiet *et al.*, 1998), and dynamic capabilities (Eisenhardt *et al.*, 2000; Rindova *et al.*, 2001; Winter, 2003; Zahra *et al.*, 2006). As identified by e.g. Aldrich and Fiol (Aldrich *et al.*, 1994), entrepreneurial activity is affected by external processes on various levels. The findings of the present study can inform entrepreneurship research regarding the external population dynamics that affect entrepreneurs' decisions to enter business – especially regarding the internal structures of industries that hold complex combinations of related but differentiated organizational forms.

For example, entrepreneurship research may adopt insights on how diverse audiences perceive existing and emerging organizational types and thus affect organizational viability. The existence of related forms and organizations under an overarching main form clearly affects the viability of creating new organizations. At the same time, resource constraints may generate competitive pressure and thus hinder organizational entry. However, such effects are constrained to the sub-population level and do not affect entry elsewhere in the main population. Combining the effects from different levels, it is possible to infer which kind of external settings are most favorable for entrepreneurial activity, and where the entry of new organizations is at its toughest. This will have impact on entrepreneurs' decisions on (i) which niches and sub-populations enter and when, and (ii) which kind of internal structures and competencies to choose and build to match the external resource endowments and externally enforced identities. In addition, the existence of externally enforced identities and forms informs how entrepreneurs adjust the mix of following and replicating existing organizational models on the one hand, and to innovate new models, on the other, to attain the best possible viability for their organizations.

The present study has also implications to strategic management, especially regarding strategic action (Barr *et al.*, 1992; Chen *et al.*, 1992a; Chen *et al.*, 1992b; Ferrier *et al.*, 1999), competitive strategy (Bettis *et al.*, 1995; Porter, 1987, 1991, 1996), strategic choice (Child, 1997; Eisenhardt *et al.*, 1992; Hitt *et al.*, 1991), and strategic groups (Cool *et al.*, 1988; Cool *et al.*, 1987; McGee *et al.*, 1986; Osborne *et al.*, 2001; Reger *et al.*, 1993). First, the strategic action literature is informed by how industry structures affect organizational viability and what kind of strategic action individual firms can take to ensure and enhance their viability as well as the general viability of their organizational form and the whole industry. For example, firms can take strategic action to promote the legitimizing effects that are favorable for the organizational form that they represent (Aldrich *et al.*, 1994; Rao, 1994). Second, researchers of competitive strategy can benefit from the increased understanding of the origins of diffuse competitive pressures. The key finding is that much of competition is originated from those firms that compete in very similar resource markets than the focal firm. Third, this again should affect firms' strategic choice of their organizational form as well as the competitive positions firms choose and communicate to their external audiences. Firms also face the strategic choice of whether to following existing organizational forms or improvise with new forms (cf. Swaminathan, 1998). Fourth, this is again linked to the strategic group literature which proposes that organizations tend to align their strategies according to other firms' strategies within the strategic group they belong to. The present study has laid out a model of identifying different strategic groups under a heterogeneous industry with a common technological base.

7.5 Methodological Implications

The present study also brings several methodological considerations to the field of organizational ecology and organizational research in general. First, even though existing research has used a systems approach to capture population heterogeneity, only a few studies have modeled all parts of the systemic structure of a heterogeneous population simultaneously. The most sophistical model of the present study featured density-dependent effects from all three levels: the main population, clusters of sub-populations, as well as the sub-populations themselves. A similar approach has been used by Cattani et al (2003) in their study of spatial heterogeneity within the Dutch accounting industry.

Second, the present study exemplifies a successful method for operationalizing the identity approach to organizational forms. In identifying the sub-forms underlying the complex biotechnology form in Finland, information was triangulated from various sources that represent several different audiences: articles from an industry journal, articles from a trade newspaper, industry directories and listings, patent data, interviews of experts with diverse backgrounds, etc. This information was then used in coding the whole population of Finnish biotechnology firms into the respective sub-populations. Thus the obtained data is likely to be more versatile and robust than in studies relying only on single sources.

A third addition to the standard ecological methodological toolbox is the use standardized density measures on the sub-population and cluster levels. This is a necessity, because the absolute sizes of the different sub-populations (and clusters, for that matter) vary drastically. The maximum density of the largest sub-population is more than ten-fold in comparison to the smallest one. Thus, the standardization is needed in order to be able to include the different sub-populations and clusters simultaneously in the same models. As discussed earlier, the models were tested without standardization, but even the simplest ones did not yield meaningful results. Indeed, doing so would implicitly assume that the turning point of the inverted-U-shaped density-entry rate curve would take place at the same absolute level of density for each sub-population (or cluster). However, there are no theoretical bases for making this assumption.

The only question left open, though, is the use of the maximum observed density as the basis for the standardization. The problem is that some of the sub-populations and clusters might not have attained their true maximum density during the observed time frame. For such populations, the standardization would distort the results. However, the graphical observation of the individual sub-population and cluster densities suggests that the magnitude of this problem remains small. It should also be noted that, in general, the justified use of weighted densities has become a well accepted practice in organizational ecology in general (cf. Baum *et al.*, 1994a; Bogaert *et al.*, 2006; Carroll *et al.*, 2000a).

A fourth methodological issue relates to the timing of entry of the de alio entrants. As explained before, de alio entrants are firms that have first operated on some other, usually adjacent field and then entered modern biotechnology. Many pharmaceutical firms are typical de alio entrants to modern biotechnology because they have produced pharmaceuticals already long before the emergence of modern biotechnology, utilizing different technological bases. When exactly should a de alio firm be considered to have become a member of the modern biotechnology population? The early trait-based approaches to organizational form would claim that entry should be coded as soon as the features of the organization match some "blueprint" of the modern biotechnology form – something which is rather difficult to operationalize. In contrast, the identity based approach would suggest instead that an explicit validation or approval by an external audience is needed for an entry event (cf. Hsu *et al.*, 2005). This again requires that the candidate organization conforms to the expected default codes imposed by the audience.

Consider, for example, a seasoned chemical or pharmaceutical company that starts using modern biotechnological methods in its core activities. How should the entry of such an actor to the population of modern biotechnology companies be coded? From the invention or availability of the first method of *modern* biotechnology? From the first instance that the firm to uses modern biotechnologies, or launching products thereof? Or from the first association of the company to the biotechnology label by some identifiable audience? The identity based approach would suggest something close to the latter, despite the possible problems in empirically measuring relevant audiences and their validations. However, similar approaches have actually been used e.g. in the case of automobile producers, whereby the entry of a firm has been counted from the official launch of the first automobile product by a producer, not the initial founding of the firm (Hannan *et al.*, 1995c). In the present study, a similar method was applied. Following the identity approach, the entry of a de alio firm was coded according to the year in which the company was first mentioned in a biotechnology context in any of the included sources. Despite the possible validity problems, this approach seems to work adequately. A much more problematic approach would have been to use original founding dates (in some cases dating back to the 19th century) and accept the problem of left truncation (cf. Carroll *et al.*, 2000a, p. 149) for these firms from 1973 backwards.

Given these methodological developments, it is proposed for further ecological research to (i) apply systems approaches that take the structure of the heterogeneous population into account in its entirety, (ii) triangulate diverse sources to operationalize the identity approach, (iii) investigate the possibility to standardize density measures, if necessary, and (iv) use the identity approach in operationalizing the timing of de alio entries.

7.6 Study Limitations and Questions Left Open for Future Research

The study has some limitations and questions left open for future research. First, the study relies on two simple systemic structures that both have a classic hierarchy. The first features a single main population and several sub-populations that are directly nested under the main population. The second structure adds an intermediate "cluster" level that is situated hierarchically between the main and sub-populations (see Figure 8 and Figure 9 on page 103). Despite the relatively good fit of these structures to the Finnish biotechnology industry, complex organizational forms might also have several other types of systemic structures. For example, McKendrick and Carroll (2001) suggest the possibility of structures such as "semi-lattices" and "diamonds".

Indeed, the structures used ignore for example how the different forms relate to each other in terms of their position in the value chain. Whereas pharmaceutical firms serve mainly the end-user markets, the *Enzymes* and *R&D Service* forms clearly represent more upstream positions in the industry. Part of their outputs may be consumed by the pharmaceutical firms. This might have implications to the systemic structure and how density-dependent processes unfold.

Another issue related to the system structure is that the present study assumes that each organization belongs to at least one of the sub-forms of biotechnology. However, it might be possible that some organizations do not naturally fall into any of the sub-populations, but instead represent a residual space between the sub-populations that still belongs to the main population. Such residual space was not operationalized to the constructs used in the present study. However, some of the firms coded to the *Bioproduction* sub-form are cases where no other relevant sub-form can be identified. Thus, in some sense, the Bioproduction sub-population represents a residual category. On the other hand, all firms in this sub-population have a common denominator that relates to production activities where either the production process or the output is biotechnological.

A second possible limitation relates to the dichotomous density variable. Each company was coded either as a member of a sub-population or not. Additionally, if a company has activities in more than one sub-population, the company was coded as a member in each of the respective sub-populations. Thus, a single company may contribute to the density of more than one sub-population. However, when counting the cluster and main population densities, each company was allowed to contribute only once for each density variable. An alternative approach would have been to use a grade of membership measure (Hannan *et al.*, 2007: 15) to divide the unit density of an organization between the relevant sub-populations. Such approach has been successfully tested by e.g. Bogaert et al (2006) for the Dutch audit industry (see also Hsu *et al.*, 2007). They have used individual employees' membership in different professional associations as the basis for calculation the grade of membership of organizations in different sub-populations. Hsu, Hannan & Kocak (2007) utilize a similar approach in studying multiple category membership in eBay auctions and U.S. feature film projects.

However, this approach was excluded from the present study because no reliable data for such grade-of-membership measures were available for the Finnish biotechnology industry. The only alternative would have been to divide the unit density of a firm equally between each of the related sub-populations. However, this would have not brought any additional information to the analysis, but would have decreased the focal company's density effect on the related sub-populations by an arbitrary amount with no real justification. A better alternative was to consider the effect of each company as equal.

A third possible limitation relates to the generalizability of the theory and findings beyond modern biotechnology to other settings with complex organizational forms. Of course, the systemic structures have to be made specific to the context, but the general idea of a systemic structure should be generalizable to other complex forms. Similarly, following standard practice of ecological research, all control variables need to be based on a detailed understanding of the historical development and structure of the specific setting under investigation. However, the types of control variables to be used have become relatively standard in ecological research (GDP, prior entries, period effects, etc.).

As discussed elsewhere (e.g. Carroll *et al.*, 1989c; Hannan *et al.*, 1995b), the density variable itself is relatively well generalizable across time, geography and the organizational setting. The same applies for the density variables used in the present study. Thus, in general, the findings should be relatively well generalizable to other settings with heterogeneous populations characterized by complex organizational forms. This is clearly a strength of the ecological approach in general. However, the flip side of the coin is that the ecological approach disregards other context-specific variables that could bring additional explanatory power (e.g. technological development, finance, and levels of education in the case of biotechnology). However, the inclusion of such variables would require substantial modifications also to the theoretical explanatory mechanisms.

Fourth, the present study focuses only on density-dependent effects originating from within the national boundaries of Finland. However, as any high-technology context, the biotechnology industry is characterized by strong international networks (Bartholomew, 1997). Many firms are highly specialized in terms of technology and products, and thus their customers, partners, and direct competitors (in terms of products and services) are often international. One could argue that part of the density-dependent effects of legitimation and competition originate outside the boundaries of Finland. Thus, additional insight and a still broader systems perspective could have been adopted by including Scandinavian or even European level measures of biotechnology density. However, no consistent enough data was available to do this. Thus the scope of the present study is restricted to the Finnish population only. However, a plausible avenue for future research would be to include still broader levels of analysis and see whether the effects of legitimation and competition still operate as predicted by the theory.

Fifth, many studies of density-dependence include a population age variable to account for age-dependent processes. Some formulations have also included age-density interactions to explain the weakening of density-dependent effects over time, as well as the late resurgence of mature populations (Hannan, 1997; Wezel, 2005).

However, because of high correlations, the age variables had to be excluded from most the models of this study. Moreover, because of the relatively young age of the modern biotechnology industry in Finland, modeling the age-density interactions were only of marginal interest.

Sixth, the density-dependent effects caused by de novo and de alio entrants might not be equal (Dobrev, 2001). De alio entrants are typically organizations that have already been in operation for years. Thus these firms often outperform the de novo entrants in terms of their relative size, experience, and resource endowments. Being larger and more professional, such firms may be able to more strongly obtain resources from the environment and also generate better visibility and endorsement among different audiences. Thus one could theorize that such organizations generate a stronger density-dependent impact of both legitimation and competition. However, because of the pooling of the entry and density data into the different population levels, there is no easy way to separate the effects of de alio and de novo organizations by e.g. using a dummy variable. Thus the models of the present study do not account for differences between de alio and de novo entrants. Future research activities would be needed to investigate how this distinction could be taken into account by e.g. adopting a specific way to weight the density variables.

Seventh, the adoption of the identity approach to conceptualize (heterogeneity in) organizational forms unveils empirical challenges in studying the emergence of new (sub-)forms and the validation of organizations as members. Unlike the pre-defined heterogeneity of spatial locations, the emergence of a new sub-form hinges upon the process by which relevant audiences agree upon (and label) a specific set of social codes that constitute the external identity of the new form. In this process, a number of organizational entries may be first required before a salient sub-form emerges around those organizations. Thus one could say that the density dependence theory contradicts in the sense that (i) it assumes that a form already exists in the minds of audiences when the first organization enters but at the same time (ii) maintains that a form gets widely accepted (i.e. legitimized) only after a number of entries have occurred.

While the theoretical issues have been discussed already in sections 2.4 and 2.5, the empirical issue remains still unsolved. In the current form of the analysis – following the general ecological research tradition – it is assumed that a (sub-)form becomes into existence upon the entry of the first organization. As discussed above, this might represent a problem of validity, since one could argue that the related (sub-)form emerges only after some critical mass of entrants has been reached.

Of course, a methodological quick-fix would be possible, such as coding e.g. the five first entrants of a new sub-population first to the general population and subsequently all firms to the new sub-population. However, at best, such a methodological trick would remain arbitrary, non-validated, and outside the research tradition in density-dependence. Moreover, the emergence of organizational forms is not the primary subject to study in the focal dissertation. Thus developing such theoretical or methodological advances falls outside the scope of the dissertation and is left to future research.

Finally, the present study does not save for the possibility that other ecological mechanisms could bring additional explanation to organizational entry in heterogeneous populations characterized by complex organizational forms. For example, a fruitful avenue for future research would be to investigate how the dynamics of niche width and resource partitioning theory (Carroll, 1985; Dobrev *et al.*, 2001) would operate given the systemic structure of the heterogeneous population.

7.7 Implications to Policy-Making and Management Practice

This study will have implications to policy-making, collective industrial action, as well as managerial practice in organizations. Consider first what is termed here as *collective institutional action*. This refers collectively to all such organizations, bodies and activities that have an impact on the focal industry as a whole. Such institutional action includes policy-making, governmental bodies and regulators, industry associations, and other types of collective action that has relevance to the industry as a whole – or one of its constituent clusters or even sub-populations. In the context of Finnish biotechnology, the Finnish Bioindustries Association (FIB), the Finnish National Advisory Board on Biotechnology (BTNK), as well as the bioteknologia.info web portal are examples of institutional action that are set to promote the field of biotechnology in General. The HealthBIO Cluster of the Finnish Centre of Expertise Programme represents a cluster level activity related to healthcare biotechnology. Last but not least, the Finnish In Vitro Diagnostic Cluster (FIVDIC) and the Pharma Cluster Finland represent activities that centralize on a specific sub-form under biotechnology.

In general, the aim of such institutional action is to advance the viability and prosperity of the field in the medium to long run. Following directly from the mechanisms of density-dependent population dynamics, such institutional action should aim to support processes that create institutionalization and legitimation, and minimize constraints that cause ecological competition.

Consider first legitimation. Policy-making, regulators, and collective industrial action are able to affect several processes that generate effects of legitimation, i.e. legitimation can be managed (Suchman, 1995). For example, institutional action can be taken to spread general knowledge about emergent forms and decrease related suspicion and uncertainty. A first step for this is the generation of a system of linguistic labels to better comprehend the underlying structures and forms. As noted earlier, such labels make the related organizational activity and categories more accessible, facilitates related communication, and advances their institutionalization. A second step is the establishment of industry associations at different levels of aggregation to promote knowledge about the field.

In addition to general knowledge also organizational diversity should be promoted. It follows directly from the findings of the present study that the existence of several sub-forms enhances legitimation effects while competition remains constrained mainly within the individual sub-populations. Thus an increasing number of sub-forms enhances legitimizing effects while constraining competitive effects. Organizational diversity can be influenced e.g. through focusing the funding of basic research to diverse enough areas, as well as making sure that educational curricula promote diversity of related industrial fields in universities, etc. (cf. Aldrich *et al.*, 1994).

Finally, collective industrial action can be taken to advance the identification and development of dominant designs and organizational forms, technological standards, and viable business strategies. Besides forums related to technology and research, industrial associations at various levels play central roles in generating such effects of legitimation. In general, as the findings show, the different forms of institutional action to promote legitimation should be most effective at the higher levels of the system. In other words, collective action operated at the level of the whole biotechnology industry or any of the clusters should be most effective in generating effects of legitimation.

Consider next competition. Institutional action may be capable of affecting the ways in which environmental resource constraints affect organizational viability, at least to some extent. Naturally, the single most effective way to affect ecological competition would be to affect the levels of demand for related products and services. However, direct methods for doing this are limited – besides cases where the demand by institutional actors such as government operated organizations can be directed to favor the focal domestic industry. However, there are indirect ways of taking institutional action to promote demand, such as organizing trade shows, promote complementary industrial activity, enhance exports, and so on.

Another way to relieve competitive pressures is to promote the availability of other types of resources. In the case of biotechnology, this would mean funding, education, academic research, and so on. In fact, the national innovation system has been quite effective of achieving this in Finland. The availability of public funding for research and commercialization has been relatively good. Similarly, the national educational system is relatively effective in Finland. At the same time it has to be noted that the Finnish biotechnology industry has performed poorly in attracting professional venture capital funding. This is clearly an issue that fosters the creation of competitive constraints on organizational entry and thus industry growth.

Consider finally management practice. Three major implications can be identified for managers. First, it may be advantageous for individual organizations to follow and even replicate existing organizational forms that have attained considerable amounts of legitimation. Similarly, inertia – i.e. sticking to the selected form – promotes consistency and thus legitimacy. Second, firms should be active in promoting the legitimation of the whole industry, as well as the clusters and the sub-forms they belong to. Finally, the understanding of complex population dynamics may be helpful for managers to identify and avoid settings with strong competitive pressures. For example, it may not be advantageous to attempt organizational entry with high sub-population density but relatively low cluster density. A much more favorable setting for entry would be high cluster density and small sub-population density. In such settings, the legitimation of the sub-form would be relatively easy, and, on the other hand, competition for sub-form specific resources would still be relatively low.

7.8 Conclusion

The present study was motivated by two key areas of interest. First, the attention was on population-level mutualistic and competitive processes that guide organizational entry and thus large-scale organizational evolution. Second, the study sought to contribute to the understanding of organizational diversity and, in particular, what implications such diversity has on the above processes of organizational evolution. The domain of organizational ecology was chosen as the conceptual and methodological basis, with density dependence as the focal theoretical framework. Building on the identity approach to organizational forms, a systems approach was adopted to capture variation within complex forms. The hypotheses were tested by data from the modern biotechnology industry in Finland between 1973 and 2006. All the hypotheses received either full or partial support. The first key finding was that the systemic structure of a complex form and the related heterogeneous population has strong implications on density-dependent entry. The second key finding was that, in such settings, legitimation tends to operate on a broader level than competition.

The study yields several extensions, implications and future research interests to organizational theory, the domain of organizational ecology, as well as the existing literatures in density-dependence, entrepreneurship, and strategic management. Methodological contributions as well as implications to policy-making, collective industry action, and management practice are also discussed. Despite some of the limitations, the present study has been able to generate a strong contribution that addresses theory, method, and practice.

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