Location Dependence and Industry Evolution: Founding Rates in the United Kingdom Motorcycle Industry, 1895–1993

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Abstract

This paper examines the founding rates of 648 motorcycle organizations in the United Kingdom between 1895 and 1993. It collates the recent findings on spatial density dependence with those related to the temporal heterogeneity of legitimation and competition. The findings of this study highlight the importance of taking into account the geographical configuration of organizational populations to comprehend their evolution.

Keywords: temporal heterogeneity, spatial heterogeneity, industry evolution

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Organizational ecologists have developed a theory of industrial evolution around the model of density dependence (Hannan 1986). This theory maintains that organizational populations evolve to steady-state densities through two counterbalancing processes of legitimation and competition. Although a considerable amount of research has been produced in support of the 'general law' of density dependence (for a comprehensive review see Baum 1996 and Carroll and Hannan 2000: Ch. 10), some of its underlying assumptions have recently been questioned. Organizational populations, for instance, follow heterogeneous evolutionary trajectories (see Lomi et al. 2001): some collapse after reaching their peak, whereas others experience cycles of resurgence and decline of different amplitudes (Ruef 2002). Owing to these inconsistencies, several scholars have recently called for an in-depth investigation of the internal factors heterogeneously affecting the evolution of organizational populations (see Boone and van Witteloostuijn 1995; Baum and Amburgey 2002).

The existing literature suggests that two fundamental sources of heterogeneity are spatial and temporal. On the one hand, recent findings have demonstrated that the effect of density-dependent forces varies over time (Dobrev 2001; Hannan 1997). This temporal heterogeneity approach underscores the inertia of organizational populations: modifications in density become decreasingly relevant to their evolution. On the other hand, another emerging line of research has challenged the idea of populations as homogenous entities, noting the presence of spatial heterogeneity (Cattani et al. 2003; Greve 2002; Lomi 1995; Sorenson and Audia 2000). Because of uneven resource distributions, for instance, different subpopulations are heterogeneously affected by legitimation and competition (see Freeman and Lomi 1994).

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Although equally insightful, these two avenues of research have remained disjointed. The present paper investigates, for the first time, the link between spatial and temporal heterogeneity, and the role of these forces in shaping organizational foundings. The goal of this work is twofold. First, it sheds light on how the spatial reach of a population influences the intensity of density-dependent processes. Second, it theoretically elaborates on how the geographical configuration of a population affects the stickiness of legitimation and competition. Empirically, this study analyses the founding rates of 648 motorcycle producers in the United Kingdom during the period 1895–1993, comparing the density-dependent dynamics of an agglomerated subpopulation with those of a scattered one. The article is organized as follows: in the next section, the theory is introduced; subsequently, the evolution of the United Kingdom motorcycle industry is presented; and then data, model, and method used for the analysis are illustrated. In the last two sections, results and their implications are discussed.

Theoretical Background

The original formulation of the density-dependent argument (Hannan 1986) can be summarized in two steps. First, density is assumed to have an impact on legitimation and competition. Second, legitimation and competition influence the vital rates of populations. That is why organizational foundings (but also mortality) can be considered a function of density. Different industries, from labour unions (Hannan and Freeman 1987) to newspapers (Hannan and Carroll 1992), banks (Ranger-Moore et al. 1991; Lomi 1995, 2000; Greve, 2002), telephones (Barnett and Amburgey 1990; Barnett 1997), beer producers (Carroll et al. 1993; Carroll and Swaminathan, 2000), and automobiles (Hannan et al. 1995; Bigelow et al. 1997; Hannan 1997; Sorenson 2000), have provided empirical evidence on the density dependence of organizational foundings and mortality.

Density dependence theory assumes that a new organizational form acquires legitimacy when it displays a template or architecture that is socially recognized (Meyer and Rowan 1977). At the time of its appearance on the market, a new form generally lacks this kind of recognition. Customers and suppliers need to be taught and educated, and employees socialized into new roles. Furthermore, it may take the institutional environment some time before the presence of a new organizational form becomes apparent. Under these conditions, an increase in density augments the social recognition of the new form, with the effect of attracting additional entrepreneurs and reducing the risk of mortality. Therefore, the density of organizations rises.

However, because of carrying capacity constraints, the industry becomes unable to accommodate a growing number of organizations. Competition intensifies because each organization depends on the same pool of increasingly scarce resources (Hannan and Freeman 1977; Hawley 1950). Marginal increments of organizations above the level of capacity of the system generate competitive pressures that act in the opposite direction of legitimation, depressing entries and increasing exits. The increase in the mortality rate (jointly with the decline of entries) is responsible for the gradual consolidation of populations. According to this well-known ecological reasoning, I hypothesize:

H1: The density of producers has an inverted U-shaped effect on the founding rates of a population.

Density Dependence and Spatial Heterogeneity

A large body of empirical evidence supports the predictions of the density-dependence theory. However, a commonly debated issue concerns to the choice of the proper unit of analysis of density dependence (see Singh 1993). By treating organizational populations as homogenous entities and disregarding sources of spatial heterogeneity, the original formulation of the theory underestimates the magnitude of legitimization and competition (Baum and Amburgey 2002; Lomi 1995). In an attempt to clarify the unit of analysis of density dependence, the study by Carroll and Wade (1991) marked a period of renewed attention to the spatial dynamics of organizational populations. Other researchers have studied smaller geographical areas (i.e. regions, states, provinces) and compared the effects of local, neighbouring and national density-dependent legitimation and competition.

Recent findings seem to suggest that legitimation and competition affect entries along a geographical gradient, with a primacy of local processes over neighbouring and national ones (Lomi 1995; Greve 2002). Lomi (1995), for instance, has provided evidence on how different clusters of rural cooperative banks in Italy reacted heterogeneously to institutional and competitive forces. For this population, he concluded that ecological models are better specified at regional than national level. In a similar vein, Greve (2002), studying entries of banks in Tokyo, remarked, '[T]aking spatial density dependence to be the result of the joint effect of spatial competition and spatial contagion suggests that the effect of a given sub-population's density gradually weakens as the distance from that sub-population increases' (Greve 2002: 854). Other recent findings support the claim that legitimation and competition are better specified locally (e.g. Cattani et al. 2003).

Besides being affected primarily by local density dependence, organizational populations often exhibit heterogeneous geographical configurations, ranging from more to less agglomerated ones. Taking their spatial reach into account is important in considering the social and institutional context within which entry decisions are embedded. As Aldrich and Fiol remarked, the standard theory implies that 'founders of new ventures appear to be fools, for they are navigating, at best, in an institutional vacuum of indifferent munificence' (1994: 645). On the contrary, would-be entrepreneurs are embedded in geographical entities characterized by distinct institutional environments and marked by heterogeneous degrees of cognitive and sociopolitical legitimation.

The lack of *cognitive legitimation* represents an important constraint for potential entrepreneurs and 'refers to the spread of knowledge about a new venture' (Aldrich and Fiol 1994: 645). Cognitive legitimation implies that a new organizational form is so familiar that it is gradually taken for granted, with the effect that 'attempts at creating copies of legitimated forms are common, and the success rate of such attempts is high' (Hannan and Freeman 1986: 63). However, founding a new venture also requires the mobilization of various resources — e.g. human and physical capital, goodwill and normative support. These resources are unevenly distributed in space because subpopulations are characterized by different degrees of *sociopolitical legitimation* — i.e. the process by which stakeholders, but also the general public, accept an organizational form as appropriate (Aldrich and Fiol 1994: 648).

Several reasons may suggest that marginal increases in density may be more effective in building legitimation within agglomerated populations than in more dispersed ones. Agglomerated populations are more likely to exhibit cumulative causation.[1] As economic geographers suggest, a peculiar feature of agglomerations is the *positive feedback* through which local growth enhances the potential of nearby locations (see, for instance, Krugman 1991). The more firms are attracted to the same location, the more attractive the agglomerated population becomes. A similar point was raised by Sorenson and Audia (2000), who concluded that 'the presence of a local industry might generally indicate the presence of local institutional factors that ease the process of resource mobilization'. In terms of sociopolitical legitimacy, the concentration of firms in a limited geographical area is also more likely to attract institutional attention. That is why marginal increments of density are instrumental in developing the distinctive institutional thickness of agglomerations (Amin and Thrift 1994, 1995). The more the local institutional environment develops, the more it will attract new firms. That is because '[E]mbeddedness in relational and normative contexts influences an organizational form's sociopolitical legitimacy by signalling conformity to social and institutional expectations' (Baum and Amburgey 2002: 315). Following this line of reasoning, it is possible to argue that the feedback loop that links legitimation to density, and boosts entries, works more effectively within agglomerated populations than in more scattered ones. Accordingly, I hypothesize:

H1a: Density-dependent legitimation exhibits a stronger positive effect on founding rates within agglomerated populations than in scattered ones.

True, organizational ecologists have also pointed out the negative implications of geographical proximity for organizational survival (e.g. Baum and Mezias 1992; Sorenson and Audia 2000). Proximate organizations experience high competition, because of their dependence on the same resource pool — e.g. labour (Sørensen 1999; Cattani et al. 2002). As the number of organizations increases, ecological competition emerges because of the struggle for the resources available. According to Carroll and Hannan (2000: 226), '[I]ntense competition causes suppliers of potential organizers, members, patrons, and resources to become exhausted ... Actors with the knowledge and skills to build organizations would be expected to defer attempts at building organizations in densely populated environments.' However, there are reasons to believe that the influence of density-dependent competition on entries is weaker in agglomerated populations than in scattered ones. That is because agglomerations are located in communities identifiable in terms of historical and cultural features (e.g. Becattini 1987) — a characteristic often overlooked by research on localized competition. The presence of cultural homogeneity reinforces consensus and tempers competition. As Piore and Sabel (1984: 266–267) put it, 'in a regional conglomeration, a breach of the standard violates not only an economic contract, but also deeply held community mores'. As a result, 'the fear of punishment by exclusion from the community is probably critical for the success of the explicit constraints on competition'. Under similar conditions, a 'collective entrepreneur' that balances cooperative and competitive forces is likely to emerge (Best 1990; Piore and Sabel 1984). Following this line of reasoning, at high levels of density, further increments have a weaker negative effect on foundings within agglomerations than in scattered populations.[2]

Recent empirical findings seem to point in a similar direction. Bigelow et al. (1997), investigating founding rates of car producers in the USA during the period 1885–1981, found that regional density-dependent competition strongly impacted on entries, but '[T]he exception to this pattern is, interestingly, the Midwest region, which is where the greatest density evolves and which, of course, emerges as the geographic center of the auto industry' (1997: 390). Similarly, Lomi (2000), analysing entries at subnational level in the Danish commercial bank industry between 1846 and 1989, found an asymmetric ecological relationship between banks clustered inside Copenhagen and those placed outside. He concluded that this population was characterized by a core-periphery pattern, with 'the capital city reacting *more responsively* [emphasis added] to diffuse competitive pressures, and "peripheral" banks in the rest of the country being more exposed to fluctuations in their local environment' (Lomi 2000: 447). Accordingly, I hypothesize that the effects of density-dependent competition on founding rates are weaker within agglomerated populations than in scattered ones:

H1b: Density-dependent competition exhibits a weaker negative effect on founding rates within agglomerated populations than in scattered ones.

Density Dependence and Temporal Heterogeneity

However, legitimation and competition are not timeless functions of density, as 'the effects of density rates on founding and mortality change systematically as organizational populations age' (Hannan 1997: 193). Although the original formulation of density dependence theory assumes a proportional effect — i.e. constant — of legitimation and competition over time, Hannan (1997) proposed an extension of the original model by elaborating on the presence of temporal heterogeneity. As far as legitimation is concerned, the role of density is particularly critical during the early years of a population: a marginal increase in density when the population is still young is more important for entries than later on. Over time, entrepreneurs become less sensitive to variation in density: associations and labour unions create a network of linkages between the organizations and other relevant agents (Carroll and Hannan 2000). The effect of legitimation, very strong at the beginning, decreases as the population ages.

Similar considerations can be made with respect to competition. In the early stage of an industry, there is no stable distinction between different producers. Competition assumes a broad ecological meaning: due to resource constraints, each organization becomes a potential competitor of the focal firm. As in the case of legitimation, at the beginning the effect of competition is remarkable. Marginal increments of density above the ceiling of legitimation promote diffuse competition within the population. As time passes, firms differentiate themselves and competition takes place within a social structure of roles (White 1981). Therefore, density-dependence competition becomes weaker as the population ages.

According to this theory, density decreases its relevance as a population matures. Yet, as Hannan (1997) proposed, density may play an important role also in the resurgence of mature populations. To cope with the limitations of the original formulation of density dependence, Hannan's rationale is that 'processes of legitimation and competition frequently interact with processes of niche width. More specifically, low density and low concentration seem to create very different conditions than low density and high concentration (often occurring late in the history)' (Hannan and Carroll 1992: 48). In particular, low density in late industries history is usually associated with high market concentration. The presence of few generalists controlling the centre of the market offers the opportunity to specialist firms to enter under-exploited regions of the resource space (cf. Carroll's resource partitioning, 1985). Thus, the contemporary presence of strong legitimation, justified by the longevity of the population (Barnett 1995), and low density (especially of generalist organizations) boosts new entries. As a result, density rises again and ecological competition re-starts until the adjustment is completed. That leads Hannan to conclude, 'instead of eroding, the potency of density revives at advanced ages, but by a more complex process' (1997: 204). Following this line of reasoning, I hypothesize:

H2: The effect of density-dependent legitimation and competition on founding rates decreases with industry age.

H3: In mature industries (i.e. at 'very high' industry age), the impact of density revives. That is, legitimation positively influences founding rates again, up to a point where the subsequent increments in density triggers competition reducing the founding rate.

Spatial and Temporal Heterogeneity Combined

The spatial configuration of a population may affect the temporal heterogeneity of density-dependent processes. Consider, for instance, how density-dependent legitimation unfolds over time. Hannan's (1997) argument maintains that, as a population matures, legitimation becomes *sticky*. As a population ages, the existence of a network of suppliers and 'a myriad of kinds of institutionalization come to substitute for density in preserving the taken-for-grantedness of a form' (Hannan 1997: 202). Besides being characterized by a dense social structure, agglomerations over time develop institutional *thickness* (see Amin and Thrift 1994, 1995). As Malmberg and Maskell (1996) have shown, a distinctive feature of agglomerations is the existence of a local network of organizations and institutions — e.g. banks, local governmental agencies — supporting local firms. Owing to the existence of a thick institutional substratum, agglomerated populations are likely to exhibit stronger stickiness of legitimation than non-agglomerated ones. Thus, not only do they experience a stronger marginal effect of legitimation, but they are also, over time, less sensitive to changes in density than more scattered ones.

As far as the forces of competition are concerned, the conclusions may be similar. Several reasons suggest that the spatial configuration of a population may shape the way in which competition unfolds over time.

First of all, since a lag is needed to move from the time in which opportunities are perceived to the availability of production capacity, 'entrepreneurs are often required to forecast the level of competition at some point in the future' (Ruef, 2002: 12). Recent research found a positive correlation between the length of this lag and the intensity of post-peak competition experienced by a population (see Lomi et al. 2001; Ruef, 2002). The longer this lag, the higher the likelihood of inaccurate estimates by entrepreneurs, and the higher the potential of a population overshooting resource capacity and exhibiting strong ex post competition. Because of a superior availability of resources — i.e. human, physical, institutional — would-be entrepreneurs in agglomerated populations are more likely to produce accurate estimates, reducing the population's risk of exhibiting long-lasting competition.

Second, since cultural homogeneity facilitates information sharing, community-based membership allows developing different forms of coordination inside agglomerated populations. Over time, the action of private associations, regional subcultures and municipalities determines the emergence of a cooperative climate that enforces the observation of social rules (e.g. Best 1990; Lazerson and Lorenzoni 1999). Besides lowering the average marginal impact of competition on new entries, agglomerated populations are prone to develop over time a 'collective action to stabilize and dampen somewhat competitive forces' (Aldrich and Wiedenmayer 1993: 163). Thus, agglomerated populations, compared with scattered ones, should also exhibit a stronger reduction of density-dependent competition over time.

Heterogeneous spatial configuration may matter with respect to resurgence in the late history of populations, too. The geographical dimension occupies a central role in Hawley's (1950) interpretation of the process through which differentiation emerges. Although the intellectual roots of resource partitioning can be traced back to Hawley's insights, the theory (Carroll, 1985) has so far been applied to non-geographical settings. An interesting exception is the work of Freeman and Lomi (1994), who found that partitioning was observable in the rural cooperative bank industry only when regional controls (i.e. dummies) were not introduced into their models. Can resource partitioning heterogeneously take place in spatially different populations? Two reasons may suggest that partitioning occurs more easily in agglomerated populations than in more scattered ones.

First of all, the model is designed for industries characterized by strong economies of scale. Economies of scale are a crucial feature of agglomerations, as the classical approach (Marshall 1922) and the new approach (Krugman 1995) to economic geography underscore. Given the importance of 'the density of large generalists' (Hannan 1997: 204) for resurgence, it is likely that these forces play a more relevant role within agglomerated populations than in more scattered ones.

Second, the speed at which entrepreneurs react to the environmental conditions leading to market partitioning is significantly affected by the time needed to collect the relevant information. As the high spin-off rates suggest (Saxenian 1994; Klepper 2002), entrepreneurs of agglomerated populations are informed about new opportunities in time. With respect to ecological competition, I expect that the general reasoning previously developed in H1b still holds. That is, density-dependent competition at late industry age decreases entries more rapidly outside agglomerated populations than inside. Therefore, I hypothesize:

H2a: The effect of density-dependent legitimation and competition on founding rates decreases more strongly with industry age within agglomerated populations than in scattered ones.

H3a: In mature industries (i.e. at 'very high' industry age) density-dependent legitimation has a stronger positive impact on the founding rates in agglomerated populations. Conversely, late competition has a stronger negative effect on the founding rates of non-agglomerated populations.

Methods

Data

As a part of a wider project on the evolutionary dynamics of the European motorcycle industry, I opted for data on the United Kingdom industry for three main reasons. First, the presence of an industrial agglomeration provides me with an almost quasi-experimental research setting to test my hypotheses on the differential intensity of density-dependent processes within and outside agglomerated populations. Second, the accurate records of the vital events allow me to avoid problems of left truncation while studying the effects of density dependence over the complete history. Third, the significant body of research on the ecological dynamics of automobile populations (e.g. Dobrev et al. 2001; Hannan 1997; Hannan et al. 1998; Torres 1995) that in many ways resembles the motorcycle ones greatly facilitates comparison and accumulation of empirical results.

The data used in this study include the entries of 648 motorcycle producers during the period 1895–1993. The main source of information is *British Motorcycles since 1900* (Collins 1998), which includes the date of birth and disbanding of each firm in the UK. The information collected was refined by consulting *The Complete Illustrated Encyclopedia of the World's Motorcycles* (Tragatsch 1977 and 2000), which is considered to be the most reliable source of this industry, and the *Enciclopedia della Motocicletta* (Wilson 1996). To test the reliability of the data, the magazines of the period were checked: *Motor Age* (from 1899), *Cycle Trade Journal* (from 1897) and *Motor* (from 1903) were consulted for this purpose. Finally, I cross-checked all the information with other references, such as *A-Z of the Motorcycle* (Brown 1997), *Historic Motorcycles* (Burgess Wise 1973), *The Ultimate Motorcycle Book* (Wilson 1993) and *Encyclopedia of Motorcycling* (Bishop and Barrington 1995).

The History of the United Kingdom Motorcycle Industry: the Role of the Coventry–Birmingham–Wolverhampton (CBW) agglomeration

The origins of the motorcycle industry can be traced back to 1885. In that year, Gottlieb Daimler created the world's first motorcycle. True, it was just a prototype that was soon to be abandoned. Thus, Hildebrand and Wolfmuller of Munich can be considered the first manufacturer of motorcycles in commercial quantities, starting from 1894. Just one year later, Colonel Holden was the first Briton to start experimenting with powered machines, in Coventry. It is no mere coincidence that the first British motorcycle was built in that area. At that time, '70% of the cycle industry was concentrated in the Midlands' (CWN 2003). At the turn of the twentieth century, Coventry had a population of 70,000, of whom 40,000 were involved in manufacturing cycles (Tragatsch 2000). A boom in cycling followed the invention of the safety bicycle in 1885 and, in 1892, 59 cycle-makers were counted in Wolverhampton alone. Coventry's Premier Cycle Company, with an annual output of 20,000 machines, claimed to have the largest cycle works in the world. Even the world's biggest producer of guns — the Birmingham Small Arms Trade Association — shifted to the production of bicycles during the same years.

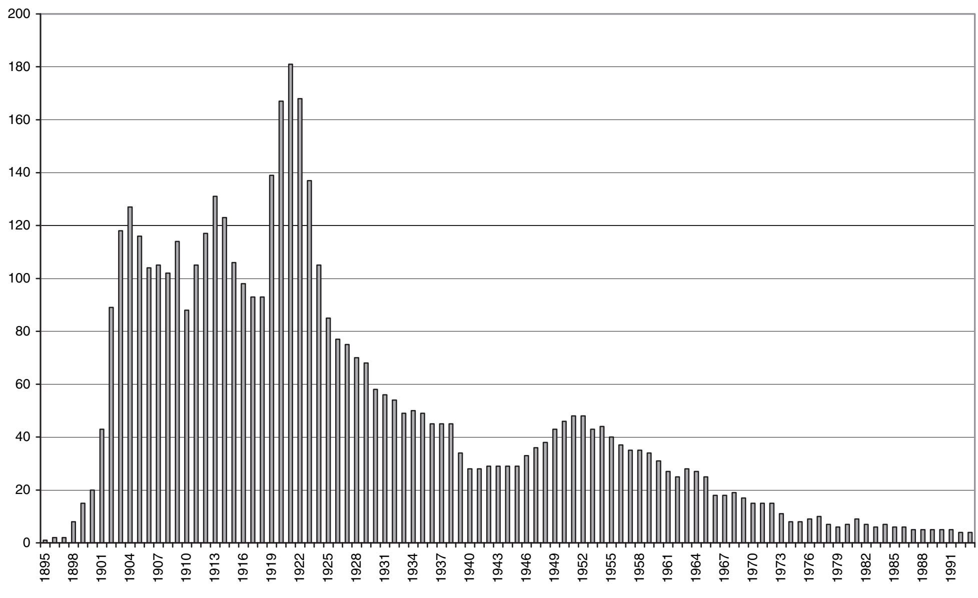
At the end of 1895, the British Motor Company of Coventry produced the first automobile. Coventry became central for the development of the motor industry and up to 65 companies, including Daimler, Rover and later on Triumph and Jaguar (1923 and 1945), entered the industry, locating their headquarters there. Similarly, Wolverhampton, a nearby city, soon became world famous for its motor cars. Soon too, the production of all kinds of motorcycles began, from the luxurious Sunbeams and Stars to the mass-produced Clynos. Villiers, a Wolverhampton-based firm, after producing bicycles for 27 years, began during the same years to produce engines, eventually becoming the largest provider in the UK. The relevance of this company for the development of the industry is witnessed by the celebration, in 1956, of its two-millionth engine, presented to the Science Museum in London.

In such a climate, the 'Coventry–Birmingham–Wolverhampton area became the centre of the [motorcycle] industry, and there were 22 motorcycle firms in

Coventry alone in the year 1905' (CWN 2003).[3] The definition of a standard position for the engine helped boost the industry, and soon 'there was a motorcycle manufacturer for every letter of the alphabet and many of them were in the West Midlands' (Birmingham 2002). In the meantime, social events, like exhibitions (e.g. the Stanley National Show in 1903) and competitions (the first was held at Richmond in 1897) helped manufacturers to build their reputation and to let people appreciate the reliability of their products. The official association of motor producers, The Cycle and Motor Cycle Association (CMCA), was founded in Coventry in 1899. In 1904, new registrations in the UK reached 21,974 motorcycles, the same as the number of cars. Needless to say, the number of producers dramatically increased: as Figure 1 shows, in 1913 the number of national producers was 131, of whom 79 were located in the 58 kilometres between Coventry, Birmingham and Wolverhampton (hereafter, CBW). After this boom, the industry experienced alternate states, ranging from entrepreneurial enthusiasm to periods of depression — see Figure 2. By the early 1920s, Britain was the world's undisputed volume producer leader and the biggest exporter. Until the 1930s, Triumph, a Coventry-based company, emerged as the national leader, but then BSA, a Wolverhampton-based company, took over just before the Second World War.

Up to 1924, there were more motorcycles than motor cars on British roads. Then, in the years between 1929 and 1934, things changed: home and export markets for motorcycles suffered a massive collapse and overall production fell from 147,000 to 58,000 units (Koerner 1995: 57). During the bombing of 1940, the Triumph factory in Coventry was destroyed. In 1942 the factory was relocated to Allesley, near Meriden (11 kilometres south of Coventry) and reopened. At the beginning of the 1950s, the need for cheap means of

Figure 1. Density of Motorcycle Producers in the UK Industry, 1895–1993



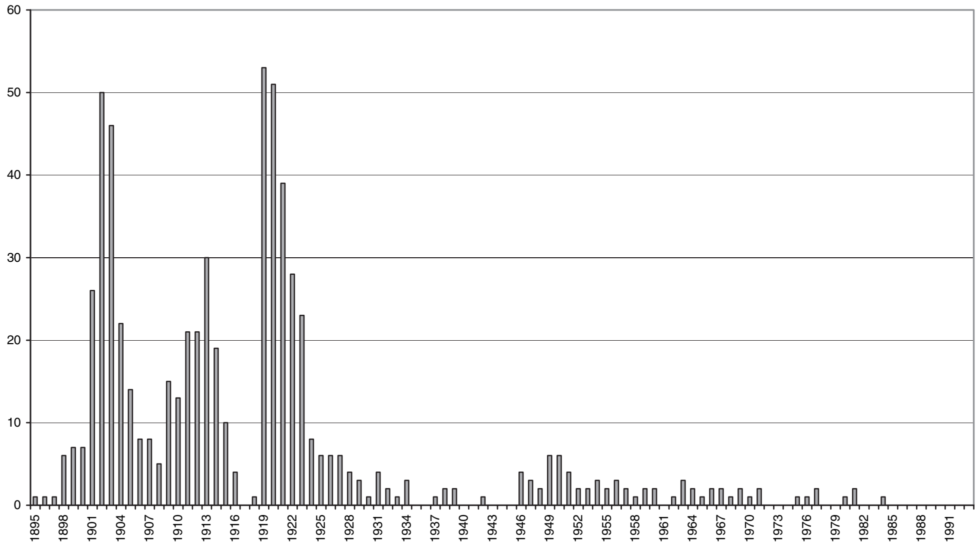


Figure 2. Entries of Motorcycle Producers in the UK Industry, 1895–1993

transportation helped the resurgence of British industry and overall production jumped to 200,000 motorcycles per year. In 1951, BSA purchased Triumph Engineering Co. Ltd, and in the mid-1950s bought Carbodies of Coventry and the Idoson Motor Cylinder Co. However, the increasing demand for small-capacity motorcycles favoured those countries that were more experienced in producing them. UK manufacturers, being mainly big-capacity producers, fell behind Italy. Eventually, in 1958, Honda entered the American and then the British markets. Figure 1 shows an oscillation in the density of producers in the years following the Second World War. It also provides evidence of a serious decline in density before the influx of Japanese competitors. That decline has continued until today, when the UK industry represents only the fourth European market for number of registrations, after Italy, Germany and France (ACEM 2000).

**Overall, nearly half the motorcycle manufacturers — i.e. 256 out of 648, including the biggest and world famous Ariel, BSA, (Royal) Enfield, Norton and Triumph — were located within the CBW agglomeration. It is no coincidence that the Museum of British Road Transport was located in Coventry, to honour the city were the ‘British motor industry was born’ (MBRT 2003). After 1896, Coventry alone had 138 car makers, more than 300 cycle manufacturers and almost 90 motorcycle builders. It has been argued that the inheritance of physical input, skilled workers and the engineering expertise of the CBW area played a crucial role in the emergence of the nearby leading industrial agglomeration designing racing cars — i.e. in the area between Birmingham, Coventry and Oxford (Pinch and Henry 1999). Figures 3 and 4 show a comparison of the patterns of entries within and outside CBW. Although the differences between the general patterns of the two figures are not substantial, the diversity of their paths to maturity provides some evidence pointing to the existence of geographical heterogenity.

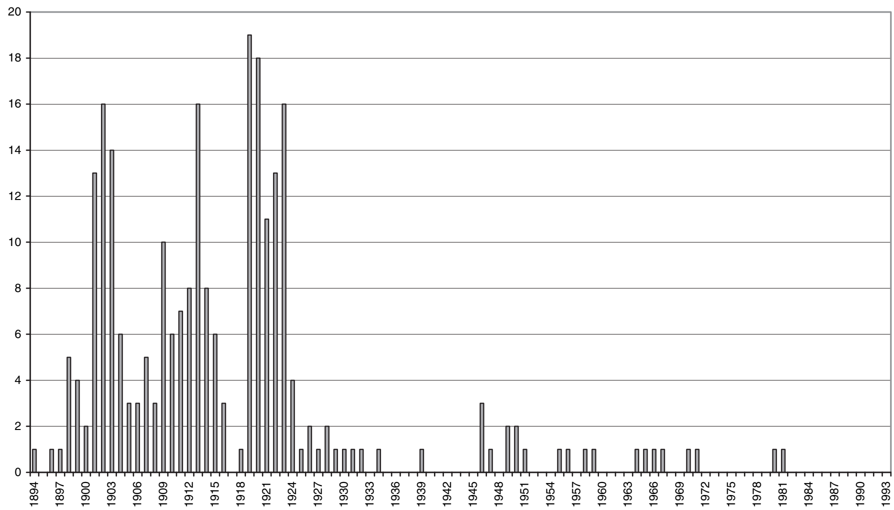


Figure 3. Entries of Motorcycle Producers within the CBW Agglomeration

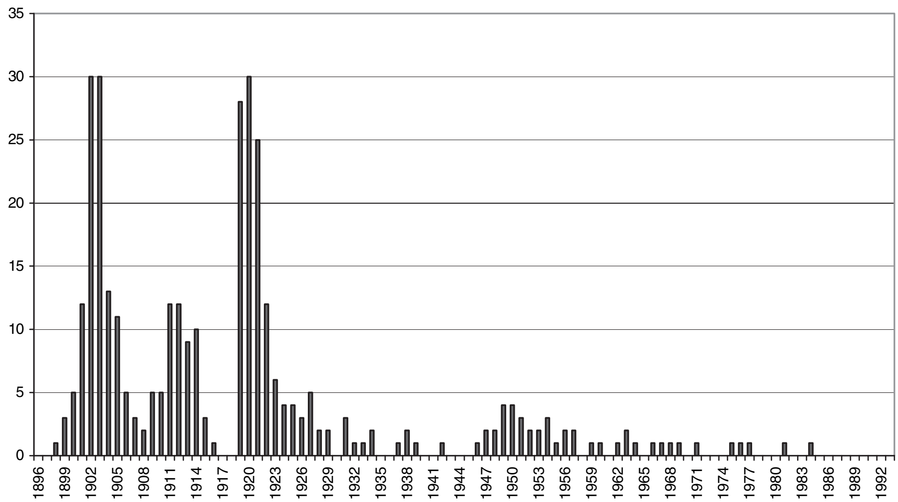


Figure 4. Entries of Motorcycle Producers outside the CBW Agglomeration

Independent and Control Variables

The interest of this paper is in modelling the effects of density-dependent legitimation and competition on entries at the national level, inside and outside the CBW agglomeration. The models estimated in the empirical part of the paper include as independent variables (i) organizational densities measured at different levels of analysis, (ii) the interactions of these measures with industry age, and (iii) a set of period effects and controls accounting for changes in the institutional/competitive environment. Three are the dependent variables of my analyses: founding rates at the national level of analysis, inside the CBW agglomeration and outside it. Exits were registered for bankruptcy or from the industry to other activities, such as, for instance, automobiles (see Carroll and Hannan 2000: 41). To avoid problems of simultaneity, all the covariates were lagged one year.

Following an established convention of organization ecologists, legitimation and competition are measured as a function of the linear and quadratic yearly number of producers — N and N^2. These measures were created at the national level, within and outside the CBW agglomeration. The year in which a previously non-existing firm sells its first product was considered as the year of birth for a firm. The *Age of the Industry* was measured by counting the number of years since 1895, the year of the first motorcycle.

To control for the general economic climate, a time-varying variable measuring the gross domestic product, *GDP*, was created using data from Maddison (1991). To control for booms of entries, the linear and the squared term of entries at time t–1 were computed: $Entries_{t-1}$ and $Entries^2_{t-1}$ Finally, nine dummy variables were created.[4] The first periods were defined with respect to the technological developments that took place in 1903 (emergence of dominant design) and 1909 (clutch, sprung forks and kick starter) — see Wezel (2002) for a detailed description. The years between 1915 and 1918 were those of the First World War. After the war, protectionism became a common trade policy and exports of motorcycles declined dramatically. The turn of 1926 — the peak density in many countries — marked the beginning of a new era defined as 'new look' (Tragatsch 2000). That year, with 580,330 motorcycles on the road, the UK represented the world's largest market (Koerner 1995). Finally, 1939 marks the beginning of the Second World War, and 1958 indicates the symbolic beginning of the Japanese era.

Models and Method of Analysis

The founding of each new motorcycle producer is assumed to be the realization of an arrival process (Barron and Hannan 1991). The Poisson regression represents the most appropriate solution for studying dependent variables that take only integer values. Nevertheless, assuming that the process of founding follows a Poisson distribution, the main problem to be dealt with is represented by over-dispersion — the tendency of the variance of the founding rate to increase faster than its mean. Although this problem does not affect the coefficient estimates, standard errors might be underestimated, and therefore chi-square values overestimated (Allison 1999). To avoid this problem, a stochastic component is added. Following Hannan (1997: 205), the effect of density measured at different levels of analysis on foundings in population i was expressed as a polynomial function of the age of the industry. In particular, polynomials are of second degree in t. By using a log-linear function to link the covariates to the rate, the formulation of the model becomes:

$$\lambda_i(t) = \exp\,[(\beta_0 + \beta_1 t + \beta_2 t^2)\,N_{it} + (\delta_0 + \delta_1 t + \delta_2 t^2)\,N_{it}^2 + \gamma' z_{it}] \cdot \varepsilon_{it}, \qquad [1]$$

where N_t and N_t^2 are the linear and squared measures of density for the population i, t measures the age of the industry, z_{it} is a vector of period effects and control variables, and $\exp(\varepsilon_t) \sim \Gamma\,[1, \alpha]$. In this formulation of the negative binomial model, the parameter alpha, estimated directly from the data, captures the overdispersion. The unobservable parameters to be estimated are

β_0, β_1, β_2, δ_0, δ_1, δ_2, γ and α. To deal with the potential correlation across observations, I used the Generalized Estimating Equations (GEE) method. GEE requires a specification of a working correlation matrix. After a preliminary analysis, an equal correlation among all the time points, i.e. exchangeable correlation structure, was found to fit my data best. The XTGEE built-in routine of STATA 7 was used for the estimates.

Results

Table 1 presents the estimates of the negative binomial models estimated for the whole population, within CBW and outside CBW, respectively.[5] The models of Table 1 test the first set of hypotheses (H1, H1a, and H1b).

Table 1. Maximum Likelihood Estimates for the Founding Rates of Motorcycle Producers in the UK, 1895–1993

Variables	National	Within CBW	Outside CBW
Constant	2.41**	2.21	.77
	(1.23)	(1.83)	(1.41)
P2 (1903–1993)	−2.06**	−2.08**	−.41
	(.82)	(.86)	(.75)
P3 (1909–1993)	.61**	.30	.003
	(.19)	(.30)	(.36)
P4 (1915–1993)	−1.40**	−1.22**	−1.90**
	(.43)	(.49)	(.41)
P5 (1919–1993)	2.13**	1.49**	2.75**
	(.73)	(.63)	(.74)
P6 (1926–1993)	−1.79**	−1.80**	−1.87**
	(.80)	(.77)	(.75)
P7 (1939–1993)	−.86	−.34	−1.40**
	(.66)	(1.02)	(.62)
P8 (1946–1993)	1.66**	1.66*	1.76**
	(.59)	(.89)	(.59)
P9 (1958–1993)	−.30	−.43	−.52
	(.30)	(.50)	(.39)
GDP	−.05**	−.060*	−.049**
	(.02)	(.034)	(.023)
Rail (in hundreds km)	−.004	−.005	.002
	(.004)	(.006)	(.005)
Entries_{t-1}	.046	.032	.15**
	(.040)	(.088)	(.05)
Entries^2_{t-1}	−.0002	.0003	−.003*
	(.001)	(.004)	(.001)
N	.053**	.099**	.058**
	(.014)	(.034)	(.028)
N^2 (thousands)	−.25**	−.73**	−.87**
	(.06)	(.24)	(.28)
Alpha	.19**	.20**	.18**
	(.06)	(.09)	(.08)
Chi-square test	18.22**(2)	8.26**(2)	16.5**(2)
Log likelihood	−193.69	−134.13	−154.77

* $p < .10$, ** $p < .05$ (Standard Errors in parentheses.) Periods were set equal to zero before the beginning of each segment of observation and equal to one from this point onward. Each effect measures the change in the rate of transition in comparison with the preceding period.

Table 2.
A Comparison of Marginal Effects of Density-Related Variables at Different Levels of Analysis

Model	National	Within CBW	Outside CBW
Density (*N*)	.11** (.032)	.12** (.027)	07** (.023)
Density² (N^2)	−.0005** (.00014)	−.0008** (.0002)	−.0011** (.0004)

**$p < .05$ (Standard Errors in parentheses.)

As the models contained in Table 1 show, all the coefficients obtained are in the expected direction and statistically significant — see N and N^2. However, since the estimates obtained involve non-linear coefficients, their values do not mirror their marginal effects. To understand the impact of the linear and quadratic effect of density on the founding rate, it is more correct to compute the 'partial derivatives of the expected values with respect to the vector of characteristics calculated at the conditional sample mean' (Lomi 2000: 445).[6] Table 2 presents the comparison of the marginal effects across populations. Interestingly enough, the estimates obtained at the national level are misleading due to unobserved spatial heterogeneity. One unit of increase of density within CBW affects entries almost twice as much as outside CBW (.12 versus 07). The opposite effect holds true when comparing the values of density-dependent competition: the magnitude outside CBW is larger than that within CBW (– .0011 versus – .0008).

Although these results seem to support the existence of spatial heterogeneity, only a qualitative approach allows a thorough evaluation of the effects of legitimation and competition across populations. The values presented in Table 3 were created using the estimates obtained in Table 1. Column 2 and column 3 (N_{min} and N_{max}) offer information on the historical evolution of the UK population, and on the CBW and non-CBW ones. The fourth column presents the maximum value of the multiplier of the founding rate (λ^*), while column 5 provides the value of density corresponding with this maximum (N^*). Column 6 contains the value of the multiplier rate at the maximum of the observed density of the population [$\lambda(N_{max})$], and the last column presents an indication of the drop of the founding rate from its peak as density goes from the expected value N^* to the observed N_{max} [$\lambda(N_{max})/\lambda^*$]. This last estimate informs us of the consequences of density-dependent competition on the founding rate.

At the maximum value of density, the founding rate at the national level increased by about 17 times ($\lambda^* = 16.9$) vis-à-vis the rate at $N = 0$. This result underscores the relevance of *legitimation*. However, the estimate obtained within CBW is far larger ($\lambda^* = 28.8$), whereas the estimate outside CBW is just one-tenth of that obtained within CBW ($\lambda^* = 2.62$). As for density-

Table 3.
Qualitative Implications of the Estimates of Density Dependence

	N_{min}	N_{max}	λ^*	N^*	$\lambda(N_{max})$	$\lambda(N_{max})/\lambda^*$
National	0	181	16.9	106	4.87	.29
Within CBW	0	92	28.68	68	18.71	.65
Outside CBW	0	83	2.62	33	.31	.12

dependence *competition*, foundings were depressed at the national level at a relatively high level of density (106). Further increment of density between 107 and the maximum observed (181) depressed the multiplier by about 71% [$\lambda(N_{max})/\lambda^* = 0.29$]. Once again, the estimates obtained are very different when spatial heterogeneity is taken into account. Density-dependent competition was much stronger outside CBW than within CBW: at the observed peak of density, the multiplier of the founding rate depressed entries almost twice as much outside as inside CBW (82% *versus* 45%). A similar pattern of results seems to provide support for hypotheses 1, 1a, and 1b. Figures 5 and 6 present these findings graphically.

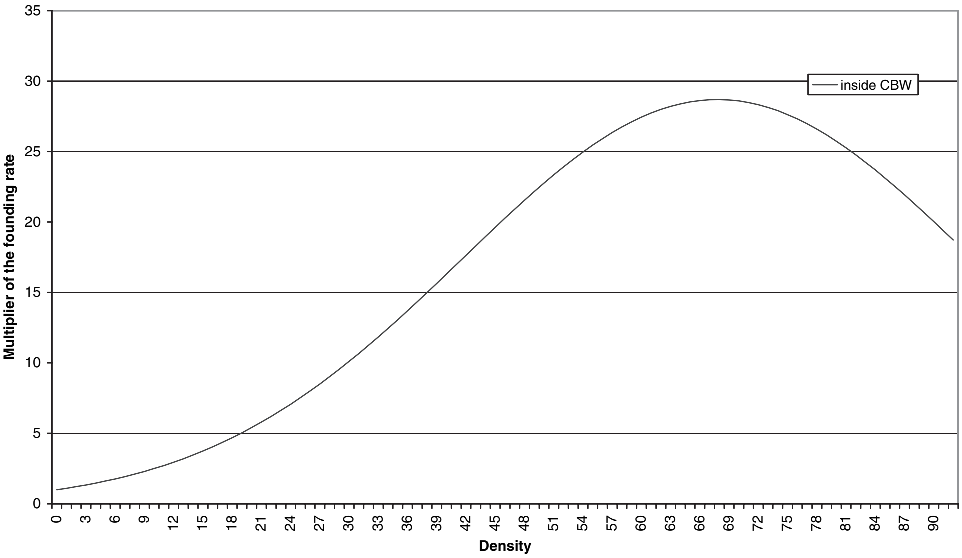


Figure 5. Multiplier of the Founding Rate within the CBW Agglomeration

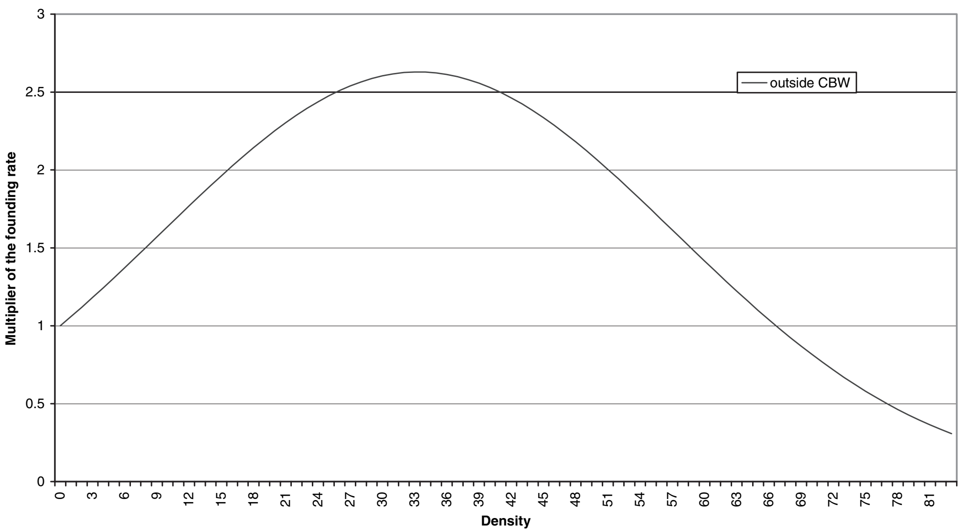


Figure 6. Multiplier of the Founding Rate outside the CBW Agglomeration

Nevertheless, comparing these effects within and outside the CBW agglomeration does not inform us about the process through which legitimation and competition unfolded over time. Hypothesis H2 suggests that the relative impact of legitimation and competition on entries declines with time. Hypothesis H3 predicts that, in the late history of the population, density effects will revive, implying a positive density-dependent legitimation and a negative late competition effect. As Table 4 shows, adding the four interactions significantly improves the fit of all the three models. The coefficients

Table 4. Maximum Likelihood Estimates for the Founding Rates of Motorcycle Producers in the UK, 1895–1993

Variables	National	Within CBW	Outside CBW
Constant	−2.62*	−6.19**	−3.74**
	(1.54)	(2.47)	(1.64)
P2 (1903–1993)	−1.95**	−.76	−1.07*
	(.95)	(.98)	(.58)
P3 (1909–1993)	1.26**	.60*	2.14**
	(.42)	(.37)	(.42)
P4 (1915–1993)	−.68*	−1.04**	−.85**
	(.41)	(.54)	(.42)
P5 (1919–1993)	3.00**	2.36**	3.81**
	(.57)	(.50)	(.51)
P6 (1926–1993)	−.88*	−.29	−1.64**
	(.55)	(.61)	(.50)
P7 (1939–1993)	−1.59*	−2.02	−1.73**
	(.94)	(1.35)	(.73)
P8 (1946–1993)	2. 72**	2.85**	2.54**
	(.76)	(1.11)	(.72)
P9 (1958–1993)	−.92**	.11	−1.34**
	(.43)	(.74)	(.51)
GDP	−.07**	−.08*	−.07**
	(.02)	(.044)	(.03)
Rail (in hundreds)	.011**	.002**	.001**
	(.004)	(.0008)	(.0005)
Entries_{t-1}	.04	.08	.17**
	(.03)	(.08)	(.05)
Entries^2_{t-1}	−.0004	−.003	−.003**
	(.0005)	(.003)	(.001)
N	.13**	.26**	.20**
	(.03)	(.07)	(.04)
N^2 (in thousands)	−.83**	−5.22**	−1.56**
	(.20)	(1.38)	(.51)
NT	−.006**	−.014**	−.012**
	(.002)	(.004)	(.003)
N^2T (in thousands)	.05**	.37**	.07*
	(.02)	(.13)	(.04)
NT^2 (in thousands)	.06**	.15**	.10**
	(.03)	(.07)	(.05)
N^2T^2 (10^{-6})	−.08**	−.64**	.012
	(.03)	(.24)	(.10)
Alpha	.07**	.05	.01
	(.03)	(.04)	(.04)
Chi-square (d.f.)	25.94** (4)	20.2**(4)	29.76**(4)
Log likelihood	−180.72	−124.02	−139.88

* $p < .10$, ** $p < .05$ (Standard Errors in parentheses.) Periods were set equal to zero before the beginning of each segment of observation and equal to one from this point onward. Each effect measures the change in the rate of transition in comparison with the preceding period.

estimated for the interactions of the density with the linear specification of time provide evidence that the intensity of legitimation (NT) and competition (N^2T) on entries declines with time. Hypothesis H2 finds support in my data. The values of the coefficients estimated within CBW are on average stronger in magnitude than those outside, providing support for hypothesis H2a, that agglomerations become less sensitive to variation in density than more scattered populations over time. As suggested by hypothesis H3, low density in late history of the industry allows legitimacy to regain momentum (see NT^2) and positively affect entries, up to the point at which competition restarts to depress them (see N^2T^2). The estimates reported in Table 4 corroborate this hypothesis. The findings with respect to the difference in these effects within and outside CBW, although the estimates obtained are similar, partly support hypothesis H3a. Specifically, the argument on late density-dependent legitimation holds, as the coefficients of NT^2 is larger within CBW than outside CBW. Apparently, industry resurgence is facilitated in agglomerated populations.[7] A puzzling result is related to late competition, which is stronger within than outside CBW. It is hard for me to interpret this result without resorting to ad hoc explanations. Nonetheless, the lack of significance of the coefficient outside CBW mirrors the findings of Hannan (1997: 214) regarding foundings in small/peripheral countries, such as Belgium.

Discussion and Conclusions

Since the seminal work of Hannan (1986), organizational ecologists have devoted increasing attention to the empirical investigation of how density dependence affects entry rates. Spatial and temporal heterogeneity lay at the core of recent studies investigating different evolutionary patterns (Cattani et al. 2003; Hannan 1997; Lomi 1995, 2000; Sorenson and Audia 2000). The present article cross-fertilizes the recent findings on spatial and temporal heterogeneity. First, it sheds light on how heterogeneous spatial configurations lead to different magnitudes of legitimation and competition forces. Second, it elaborates on how the geographical reach of a population influences the way in which density dependence unfolds over time. Empirically, I addressed these issues using the information collected on 648 UK motorcycle producers during the period 1895–1993. By and large, the findings of this article support the claim that the geographical configuration of a population influences both the intensity and the stickiness of legitimation and competition. The results obtained provide strong support for the revised density dependence theory proposed by Hannan (1997).

The implications of this study are twofold. First, jointly considering temporal heterogeneity and the spatial reach of a population may improve our understanding of the evolution of organizational populations. In particular, the findings concerning the competitive dynamics of agglomerated populations are intriguing: the CBW agglomeration experienced, on average, a weaker marginal effect of density-dependent competition on the founding rate.[8] A similar result emphasizes the importance of considering the social and geographical context within which demographic events are embedded. Why? As, for instance, the cost of social interaction increases with geographical distance (Lazersfeld and Merton 1954), agglomerated populations are more likely to exhibit learning (e.g. Miner and Anderson 1999). Similarly, the institutional thickness of agglomerations is positively associated with the stickiness of legitimation. Conversely, the lack of cultural homogeneity of a scattered population reduces the amount and pace of knowledge transfer at the population level (Waller and Carpenter 1999). That explains why collective action dampening competitive forces (Aldrich and Wiedenmayer 1993) is more likely to occur within agglomerated populations. Not surprisingly, other authors have pointed out the lower effect of density-dependent competition on the founding rates of agglomerated populations (Bigelow et al. 1997; Sorenson and Audia 2000). By elaborating on the temporal heterogeneity of this average result, I believe that this paper makes an initial step in the direction of understanding why and how populations may heterogeneously react to equivalent evolutionary forces.

Second, the findings of this paper underscore the need for geographical definitions of density-dependent legitimation and competition. Although other scholars already stressed the importance of spatial heterogeneity within organizational populations (e.g. Greve 2002; Lomi 1995), this paper elaborates on how spatial configurations affect the unfolding of density dependence over time. Since the majority of ecological studies fundamentally lack an explicit geographical space, I argue that the literature on agglomeration economies may provide useful insights (see, for instance, Krugman 1993). As already pointed out by van Wissen (2002), the concept of legitimation is similar to that of cumulative causation/positive feedback used by economic geographers to explain the emergence of agglomerations. This literature pointing to the time-varying nature of carrying capacities may provide new insights to understand the dynamics of competition. Moreover, my findings can be interpreted as a first step in the direction of improving our understanding of partitioning processes (Carroll 1985). *Where* does partitioning take place? *Where* do entrepreneurs locate their businesses during different stages of the industry life cycle? The findings of this paper suggest that addressing these questions requires considering the geographical reach of organizational populations.

In its present form, this work suffers from at least two main limitations. I believe that each limitation can be associated with a specific direction for future research that may be pursued. The first limitation concerns the representation of the boundaries of the populations under study. Building on the insights of historical information, I decided to define the relevant spatial boundaries dichotomously: within and outside CBW, implicitly assuming that these boundaries are impermeable. While this choice is probably appropriate during the first half of the period covered by my sample, it is probably decreasingly correct during the second half. The estimates obtained from cross-density effects show that CBW density had a stronger impact outside CBW foundings than vice versa, confirming the existence of a core-periphery structure. Future work could focus on the dynamics of such cross-level density effects in more detail. Second, similarly to Hannan (1997), this paper theorizes on the role of density in market partitioning (Carroll 1985), without taking organizational size into account. Different and considerably more detailed data are needed to address these limitations, and to articulate the core propositions of this paper more convincingly. In spite of these limitations, this work sheds light on the interplay between spatial and temporal heterogeneity. The challenge of understanding the evolutionary trajectories of organizational populations is still open, and taking geography into account is critical to an understanding of the differences, instead of the regularities, marking the evolution of organizational populations.

Appendix

Maximum Likelihood Estimates of the Complete Models for the Founding Rate of Motorcycle Producers in the UK, 1895–1993

Variables	National	Within CBW	Outside CBW
Constant	1.11	6.20	1.32
	(3.16)	(7.44)	(3.05)
$Entries_{t-1}$	.07**	.07	.16**
	(.03)	(.08)	(.05)
$Entries^2_{t-1}$	−.001**	−.003	.003**
	(.0005)	(.004)	(.001)
N	.14**	.29**	.21**
	(.03)	(.07)	(.04)
N^2 (thousands)	−1.02**	−5.61**	−1.73**
	(.17)	(1.75)	(.56)
NT	−.008**	−.016**	−.012**
	(.002)	(.005)	(.004)
N^2T (thousands)	.071**	.40**	.011*
	(.018)	(.13)	(.006)
NT^2 (thousands)	.10**	.22**	.016**
	(.03)	(.10)	(.008)
N^2T^2 (10^{-6})	−.13**	−.73**	−.09
	(.043)	(.24)	(.15)
Industry age	−.04	.06	.11
	(.93)	(.14)	(.10)
Industry age^2	−.0006	−.003	−.002
	(.001)	(.003)	(.002)
Alpha	.05	.04	.005
	(.03)	(.04)	(.033)
Chi-square (d.f.)	4.1(2)	4.3(2)	1.7(2)
Log likelihood	−178.63	−121.85	−139.01

* $p < .10$, ** $p < .05$ (Standard Errors in parentheses.) Period effects and controls, although estimated, are omitted from the table.

Notes

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1 Cumulative causation is the process by which one region of a country becomes increasingly the centre of an economic activity.

2 An alternative explanation for the weaker effect of density-dependent competition on the founding rates of agglomerations is provided by Sorenson and Audia (2000): because of their superior opportunity structure, high density is likely to attract new entrepreneurs. Thus, density can be considered to be predominantly a positive effect on foundings (see footnote 18, p. 447). Although intriguing, their explanation is difficult to reconcile with a theory of temporal variation density-dependent legitimation and competition. Furthermore, from an empirical standpoint, their analysis is based on left-censored data, whereas mine is not.

3 Interestingly enough, in the same years the aircraft industry also developed in Coventry — see http://www.coventry.org.uk/heritage2/industry/aircraft/.

4 The dummies were set equal to zero before the beginning of the segment of observation, and put equal to one from this point onward. Each effect measures the change in the founding rate in comparison with the previous period. The advantage of using this technique is to compare close periods, instead of relating them to the first or the last.

5. The model selection follows a forward process, starting from the simplest formulation and advancing to more complex ones. The initial model contains only period effects [Z]. At each stage, the next model is adopted only if the null hypothesis ($\chi^2[L_2 | L_1] = 0$) is rejected at the significance level of .05. Adding main effects when they are non-significant increases the standard errors, and negatively affects the parsimony of the model (Aiken and West 1991; but see also Hannan 1997: 213). That is why the main effects of industry age are omitted from the final formulations. However, in the Appendix, the estimates of the complete models are presented.

6. The values reported in Table 2 were obtained from the following formula: $\partial E[y_t|x_t]/\partial x_t = \lambda_t \beta = E[y_t|x_t]\beta$.

7 The analysis of the marginal effects of the coefficients of the interactions is in line with the discussion of the results presented here. Another way to interpret the coefficients of Table 4 is to compute the value of the multiplier at different observed values of density and compare them across populations. Such a comparison is facilitated by the similarity of the trajectories followed by the two subpopulations. According to these estimates, during the early years of the industry, the stronger effect of legitimation within CBW is net: in 1901, for instance, the estimate of the multiplier within CBW is 10.93, and 6.5 outside. During fierce competition, as in 1924, the multiplier within CBW is still above 1, at 1.34, whereas outside CBW is just 0.13. When facing low levels of density, as in 1945, the stickiness of legitimation within CBW is partly mirrored into a multiplier of 0.31, double that obtained outside CBW — i.e. 0.15. Lastly, late competition was stronger within CBW than outside CBW: in 1958, for instance, the corresponding values of the multiplier are equal to 0.04 and 0.16.

8 The reader may argue that this result runs against some ecological findings on localized competition (e.g. Baum and Mezias 1992; Sorenson and Audia 2000). Consider, for instance, Baum and Mezias' (1992) study on the Manhattan hotel industry. The main insight of this paper is two steps. First, they show that locating closer to other hotels in Manhattan increased a hotel's survival chances. Second, they provide evidence that this benefit of agglomeration diminishes with increasing numbers of neighbouring hotels in closely bounded areas. Shedding light on this dual nature of agglomeration economies in foundings is difficult, because individual attributes — e.g. geographical distance between firms — cannot be observed for organizations that do not yet exist (see Hannan 1991). Future extensions of this work may investigate the survival consequences of localized competition.

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