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EVOLUTIONARY GAME THEORY AND ORGANIZATIONAL ECOLOGY

THE CASE OF RESOURCE-PARTITIONING THEORY

CHAOHONG ZHOU & ARJEN VAN WITTELOOSTUIJN

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RESEARCH PAPER 2009-002
ACED 2009-001
MAY 2009

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D/2009/1169/002
ACED/2009/001

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Revised Draft

August 2008

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ABSTRACT

In this paper, we construct a mathematical model that applies tools from evolutionary game theory to issues in organizational ecology. Evolutionary game theory shares the key feature of mathematical rigor with the industrial organization tradition, but is similar to organizational ecology by emphasizing evolutionary dynamics. Evolutionary game theory may well be a complementary modeling tool for the analytical study of organizational ecology issues, next to formal logic, standard game theory, and agent-based simulation. We illustrate this claim in the context of resource-partitioning theory. We assess the impact of an organization population's resource space shape and scale economies on organizational performance and market evolution. The model demonstrates that the shift of resource distribution from homogeneous (heterogeneous) to heterogeneous (homogeneous) benefits specialism (generalism). On top of that, we offer a new result by revealing the distinct effects of external and internal scale economies on market evolution.

Key words: evolutionary game theory; organizational ecology; resource partitioning; competitive dynamics

INTRODUCTION

Organization ecology (OE) is one of sociology's prominent theories of the evolution of organizational populations. Drawing on insights from bio-ecology, Hannan and Freeman (1977) suggested a Darwinian selection approach to issues of organizational population evolution, emphasizing the role of competition and legitimation in shaping the population-level vital rates of organizational founding and mortality. Since 1977, hundreds of studies have been published in the OE tradition. By far the majority of these studies share an empirical focus, applying event-history analysis to impressive unbalanced panel data sets of a wide variety of organizational populations (for overviews see, e.g., Hannan and Freeman, 1989, Hannan and Carroll, 1992, and Carroll and Hannan, 2000a). Theory-wise, this type of studies is dominated by verbal arguments leading to hypotheses that are then tested empirically. Next to this, though, OE has developed a remarkable tradition of applying formal (first-order or non-monotonic) logic. This turn was triggered by the entry into OE scholarship by two Hungarian logicians in the early 1990s: Gábor Péli and László Pólos. By now, their formal logic approach is well established, as witnessed by the close collaboration of the prominent organizational ecologists Mike Hannan and Glenn Carroll with László Pólos (see, e.g., their 2007 book), and the recent contribution of Péli and Bruggeman (2007).

In the current paper, we suggest another, complementary quantitative approach to theory-building in OE: evolutionary game theory. As argued by van Witteloostuijn, Boone and van Lier (2003), game theory might well be an appropriate tool to study OE issues. Game theory is widely applied to the study of competition in industrial organization (IO) economics, focusing on the impact of features of organizations and rules of games on competitive outcomes (van Witteloostuijn, 2002). In so doing, the implications of the direct interaction between the agents driving the Darwinian processes emphasized by OE can be analyzed. In extant OE theory, based on either verbal argumentation or formal logic, the emphasis is on indirect competition. As a result, the theory of the underlying processes at the micro level of interacting organizations is not as developed as it could be.[1] To date, though, the number of game-theoretic models of OE is very limited indeed. In fact, to the best of our knowledge, the model presented below is the second one only, next to van Witteloostuijn et al. (2003) referred to above.

A key reason for this might be that 'standard' or classic game theory is too static in nature, and based too much on neo-classical economics' assumption of agent rationality. As a consequence, standard game-theoretic tools are only able to capture parts of the evolutionary processes that are so central to OE. For sure, 'standard' game theory is not static to the extent often thought by non-users. The example of sequential games is a case in point (Fudenberg and Tirole, 1991). Then, different types of games are linked dynamically, analyzed by applying tools such as backward induction and subgame perfectness.[2] Moreover, standard game theory is so flexible that it can easily absorb all kinds of non-rationality. For instance, in the Beckerian tradition of microeconomic modeling, other-than profit objectives have been studied in game-theoretic models of competition (Vickers, 1985). However, there is a branch of game theory, originating in biology, which is intrinsically dynamic and explicitly based on an assumption of bounded

[1] This is not to say that game theory is the only quantitative theory-building toolkit that can achieve this – certainly not. Another prominent example is agent-based simulation modeling (for examples of agent-based simulation modeling in OE, see García-Díaz and van Witteloostuijn, 2007, and García-Díaz, Péli and van Witteloostuijn, 2008).

[2] Related to this is the dislike for equilibrium thinking in OE. Equilibrium thinking can be nicely combined with an emphasis on dynamic processes, however, as is already clear in Walras' argument that dynamic

rationality: evolutionary game theory (EGT). This why we believe that applying EGT to issues in OE is particularly promising.

Below, we will first briefly introduce the key building blocks of EGT. The proof of the pudding is in the eating, though. Therefore, next, we will apply EGT to a well-known OE theory fragment: resource partitioning. In so doing, we hope to illustrate how EGT can be used to model the micro-level processes of interacting organizations that, ultimately, produce macro-level resource-partitioning outcomes. Moreover, we show how the application of EGT is instrumental in deriving new results, particularly by revealing the differential impact of external versus internal scale economies, which went unnoticed in earlier non-formal work in the resource-partitioning tradition.

EVOLUTIONARY GAME THEORY

Backbone

EGT provides a formal toolkit for studying the robustness of strategies or rules under the influence of evolutionary forces in the context of games played by boundedly rational agents (Tirole, 1988; Weibull, 1997). In EGT, the criteria of rationality and self-interest as usually assumed in classic game theory are generally (but not necessarily so) replaced by those of bounded rationality and Darwinian fitness (Maynard Smith, 1982). Conceptually, EGT has roots in biology (e.g., Fisher, 1930; and Hamilton, 1967) and economics (e.g., Alchian, 1950; and Friedman, 1953). Formal EGT was pioneered by Maynard Smith and Price (1973) and Maynard Smith (1982) in the context of bio-ecology, though. Only later, formal EGT spilled over to economics. Maynard Smith and

processes can be captured by modeling a sequence of temporary equilibria (van Witteloostuijn and Maks, 1990).

Price (1973) introduced the central concept of the evolutionarily stable strategy (ESS). Since then, EGT has been developed further in one of two ways (Samuelson, 1997). On the one hand, the ESS concept was widely employed as a tool of analysis in studies of dominance of (pure) strategies. On the other hand, Darwinian dynamic processes have been studied by focusing on the evolution of the proportion of different (mixed) strategies at the population level, using such newer tools as replicator dynamics and evolutionary equilibria.

Although evolutionary thinking has a long tradition in economics, dating back to classic economists like Thomas Malthus (1798) and Joseph Schumpeter (1943), it is only since the 1990s that EGT has become of increased interest to economists and sociologists. Since then, there has been an upsurge of economic research applying and developing EGT, witnessed by special issues of or review articles in influential journals such as *Games and Economic Behavior* (1991), *Journal of Economic Literature* (1992) and *Journal of Economic Behavior and Organization* (1996). However, as Hopkins comments, “there has not been much consideration of economic problems, such as the analysis of markets or the behaviours of firms or consumers” (Hopkins, 1995: 102). The majority of this research has been done by pure mathematicians and game theorists, rather than by applied economists. However, EGT is widely applicable to economic issues (Friedman, 1998). Promising areas of application include IO, economic development, international trade, policy analysis, market evolution, labor market convention, and much more (Hopkins, 1997; Friedman, 1998). For example, Axelrod (1981), Young (1993), Friedman and Fung (1996), and Rhode and Stegema (2001) have applied EGT in these areas.

With its emphasis on micro-level bounded rationality in combination with a focus on the evolution of macro-level structures, EGT offers a nice toolkit for the analysis of sociological issues, too. Indeed, recently, EGT entered into sociology as well, although the number of EGT applications in sociology (and management, for that matter) is still very limited. Two examples are Zhang (2004) and Chiang (2007). Zhang (2004) offers an EGT model of residential segregation, and Chiang (2007) presents an EGT analysis of the evolution of strategies in so-called ultimatum games. In the present paper, we will not attempt to offer a comprehensive survey of the larger EGT literature. Rather, we will illustrate central concepts of EGT by discussing the example of a game with two competing strategies, or forms (say, generalist *vis-à-vis* specialist strategies), which offers a nice steppingstone for our EGT model of resource partitioning.

Consider a market inhabited by two types of organizational forms, or strategies: I and J (say, generalist and specialist firms). In the terminology of EGT, both strategies represent economically distinct roles in the population (Friedman, 1998). All firms active in the market jointly constitute a population. Since we consider only one market, the so-called number of the population, K, is 1.[3] Each individual agent (here, firm) in this population must adopt one of two alternative strategies: I or J (or a generalist or a specialist strategy). In EGT terminology, I (generalism) and J (specialism) can be viewed as two pure strategies. The state of the population specifies the fraction of I or J firms (i.e., the fraction of the two pure strategies). Formally, the population state is defined by the vector $x = (x, 1\text{-}x)$, where x and $1\text{-}x$ are the population share of the I and J strategies,

[3] If there is another market, the population number would be $K = 2$, because firms in the two markets are economically distinct in that they face different demand and supply configurations. With $K \geq 2$, EGT offers ample opportunities to study issues related to multi-population or community ecology. For now, however, we focus on single-population EGT.

respectively. This reflects a so-called one-dimensional game, involving one population ($K = 1$) and two pure strategies (I and J, or generalism and specialism).

EGT generally assumes that games take the form of a sequence of pair-wise contests[4] over time. So, EGT deals with dynamic direct competition. Table 1 shows the payoff matrix associated with our symmetric game, with cell entries representing the fitness payoffs to the row player.

[Insert Table 1 about here]

Given this payoff matrix, EGT's key question is: what will be the eventual population equilibrium in terms of strategy shares? There are two approaches to address this central question. On the one hand, EGT's notion of an <u>evolutionary stable strategy</u> (ESS) is directed at determining the stationary end state of the evolutionary process with a focus on finding proof for the existence of an unbeatable strategy, immune against any mutuation, in which agents are programmed with either pure or mixed strategies. On the other hand, EGT offers the two-fold tool of <u>replicator dynamics</u> (RD) and <u>evolutionary equilibria</u> (EE) to study dynamic evolutionary processes with a focus on selection of a (possibly ESS) equilibrium strategy, in which agents are programmed with pure strategies. Both approaches are described below in turn.

[4] Maynard Smith (1982) argues that evolutionary games are not necessarily characterized by pair-wise contests. An alternative is "playing the field", in which an individual agent is competing not against another individual opponent, but rather against the population as a whole. In economic applications, Friedman (1998) argues that neither of both conditions—pair-wise contests of two individual agents or playing the field—reflects a necessary assumption for evolutionary game models. Note that pair-wise contests *vis-à-vis* playing the field evolutionary games nicely reflect the issue of direct *vis-à-vis* diffuse competition (cf. van Witteloostuijn et al., 2003). EGT can be applied to study both. Here, for the sake of illustration, we focus on pair-wise contests.

Evolutionary Stable Strategy (ESS)

ESS was first put forward by Maynard Smith and Price (1973). It is defined as "a strategy such that, if all members of a population adopt it, then no mutant strategy could invade the population under the influence of natural selection" (Maynard Smith, 1982: 10). In the bio-ecology setting for which EGT and ESS were designed, this relates to Darwinian evolution examples where within a population of a specific species (say, giraffes with long necks – here *I*) a mutant emerges (say, giraffes with short necks – here *J*), for whatever reason.[5] The question is whether *I* or *J* turns out to be more fit than its counterpart in the battle of pair-wise contests. So, in the current paper, we focus on single-population EGT, leaving multi-population (or community) extensions to future work.

Following Maynard Smith (1982), we illustrate the ESS concept by considering a population consisting mainly of *I*, with a small frequency *p* of some mutant *J*. The fitness of strategy *I* and *J*, respectively, are

$$W(I) = (1 - p)E(I,I) + pE(I,J), \text{ and} \tag{1}$$

$$W(J) = (1 - p)E(J,I) + pE(J,J). \tag{2}$$

If *I* is evolutionary unbeatable (and hence an ESS), it must have the property that, if all members of the population adopt *I*, then the fitness of each typical *I* member is greater

[5] This illustrates the population concept as well. All population members are of the same species (giraffes), though with different 'strategies' (long versus short necks). Starting from this set of notions, OE defines all members of a population as having the same 'form' (say, beer brewers), albeit members may be different in terms of strategy (say, generalist versus specialist, or cost leader versus product differentiator). This type of reasoning triggered a heated debate between OE and non-OE scholars back in the 1980s about definitional and boundary issues. However, such issues need to be resolved by any researcher interested in 'markets',

than that of any possible mutant *J*; otherwise, a mutant *J* could invade the population, beat a weaker *I* member in a pair-wise contest, implying that *I* would not be evolutionary stable. Since *I* is an ESS, $W(I) > W(J)$. Since $p << 1$, for all $J \neq I$, this requires

$$\text{either } E(I,I) > E(J,I) \text{ or } E(I,I) = E(J,I) \text{ and } E(I,J) > E(J,J). \tag{3}$$

That is, *I* must outperform *J* playing against *I* rather than *J*, or *I* must not only perform as well as *J* against *I*, but also has to outperform *J* when both play against another *J*. This is a key argument: any strategy *I* satisfying one of both two conditions is an ESS (Maynard Smith and Price, 1973).

Three subtleties need to be born in mind to fully understand the ESS concept. First, an ESS is immune to invasion by a competing strategy: whatever mutant *J* enters into the population, *J* will be beaten by *I* (Maynard Smith, 1982). Second, an ESS also fares well against competitors who also play the ESS (Parayre and Hurry, 2001), and thus an ESS is stable under widespread imitation, thriving even though all the members use the ESS to compete against each other: all population members adopting *J* will not trigger devastating cannibalization. Third, given its higher fitness value, the ESS can therefore invade sub-populations dominated by other strategies, and replace the latter over time (Parayre and Hurry, 2001): if *J* retreats into a corner (or niche) of the population, *I* will drive *J* out of that corner in a series of pair-wise contests.

'industries' or 'populations', whether they work in OE or not (e.g., industrial organization, institutional theory or competitive strategy). Here, we ignore these issues.

Replicator Dynamics (RD) and Evolutionary Equilibria (EE)

The ESS in EGT is actually a refinement of the Nash equilibrium concept in 'classic' game theory. However fundamental it is, its logic must be extended to broaden the applicability of EGT. Particularly, although ESS is the crucial concept to understand evolutionary stability, the following two disclaimers make this rather static approach unsatisfactory (Vega-Redondo, 1996). First, in many types of games [e.g., in the so-called Rock-Scissors-Paper (RSP) game], the existence of an ESS is not ensured. Second, the concept of ESS makes pronounced theoretical sense only if the population is monomorphic – i.e., if all individual members are, in equilibrium, playing the same strategy. Third, and related, specific dynamics are implicit in the ESS concept (Weibull, 1992; Vega-Redondo, 1996): if the ESS strategy is confronted with any small mutation, the fact that the latter performs worse than the ESS leads to the implicit dynamic assumption that the mutation will eventually disappear altogether.

These issues have directed research attention to dynamic evolutionary game models that address the evolution of the state of population, focusing on dynamic non-monomorphic processes, rather than on static monomorphic end states only. Again, this nicely echoes OE's emphasis on ecological processes as well, much more so than the corner equilibrium states implied by the ESS concept. Samuelson (1997) rightly points out that the study of such dynamic models will play – and indeed does so – a central role in assessing the applicability and validity of evolutionary stability concepts. Among the various dynamic EGT tools, replicator[6] dynamics has been widely studied by biologists

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[6] According to Hofbauer and Sigmund (1992: 147-148), replicators are the "units of selection" (i.e., the lowest level at which selection takes place), and are "any entities, in the definition of Dawkins, which can get copied and which satisfy the following two conditions: (a) Their properties can affect their probability of being copied; (b) The line of descendent copies must be—at least in principal—unlimited." Segments

and economists alike, the latter with the help of adding a small set of simplifying assumptions (Samuelson, 1997). The RD tool was initially advocated by Taylor and Jonker (1978). RD refers to a system of deterministic differences or differential equations. Within bio-ecology, RD essentially "represents a direct formalization of Darwinian process of selection, i.e. a process by which those strategies that prevail in the long run are merely those that reproduce faster" (Vega-Redondo, 1996: 85).

For the sake of clarity, again, we focus on a one-dimensional game involving one population with strategy choices $I = 1,\ldots,N$.[7] Let Ei denote the i^{th} pure strategy, x the state of the population, and $f(Ei)$ the fitness of strategy Ei. In this case, x_i stands for the fraction, or share, of the i^{th} strategy in the population. Following Hofbauer and Sigmund (1992), RD is formulated mathematically as

$$\frac{\dot{x}_i}{x_i} = f(E_i) - \overline{f}(x), \qquad (4)$$

where $\overline{f}(x) = \sum x_i f(Ei)$. Equation (4) states that the growth rate of the share of the pure strategy Ei is directly related to this strategy's relative fitness – that is, the absolute fitness of pure strategy Ei minus the population-weighed average fitness $\overline{f}(x)$.[8] The assumption underlying the above game's dynamics is, as stressed by Hofbauer and

of RNA or DNA are replicators in the strict sense, and organisms, phenotypes, groups and species are viewed as replicators in the simple ecological models in which individual differences are ignored.

[7] So, we now have more than two strategies, or mutants. In the example above, with I and J, $N = 2$. In the RD example, we illustrate how an EGT model can be easily expanded to include more than two strategies.

[8] Having such difference or differential equations in place offers ample opportunities to analyze a wide variety of complex non-linear dynamic processes (see, e.g., van Witteloostuijn and van Lier, 1990, in IO and Ruef, 2004, in OE).

Sigmund (1992: 124), that “the success of strategy *Ei* corresponds to its rate of increase, and thus tacitly that ‘like begets like’.”

Related to RD is the evolutionary equilibrium (EE) tool. An evolutionary equilibrium (Friedman, 1991, 1998) occurs at the state x^* where all strategies are equally fit. Implied by the definition of Friedman is that all states close to the EE will eventually evolve toward x^*. The EE is thus locally asymptotical stable. That is, any small perturbation from the steady state x^* will return to x^*. Additionally, an EE may be globally stable as well. Then, any perturbation from the steady state x^*—however large or small—will return to x^*.

The essence of RD and EE is that, following the basic tenet of Darwinism, fitter genotypes increase in number relative to less fit genotypes. The economic (and OE) analogue is that, due to imitation and learning or entry and exit, organizations with fitter strategies increase in density relative to their counterparts with less fit strategies in every population (Friedman, 1998). In biology, fitness has been equated with the (sub)species' population growth rate, the ability to pass on alleles, an unspecified measure of survival and reproductive prowess, a tendency to leave more or fewer offspring, the product of fertility and survival, or the net reproductive rate of the population (McGraw and Caswell, 1996). In OE, the emphasis is on the vital rates of organizational founding and mortality (Hannan and Freeman, 1977), which is akin to the population's net reproductive rate. In principal, this is a scalar estimate for reproductive success (Hofbauer and Sigmund, 1992). In economics, depending upon the application at hand, fitness might involve profit, a financial return measure [such as returns on assets (ROA), equity (ROE) or sales (ROS)], market share, economic growth, and more. In OE, Hannan, Carroll and Pólos (2003a) emphasize the impact of competition on fitness, viewing fitness as an organization's ability to thrive in the face of competition.

RESOURCE-PARTITIONING THEORY

As said above, the core of the current paper is an illustration of the applicability of EGT to OE issues by developing an evolutionary game model of resource partitioning (RP), a prominent theory fragment in OE. To set the scene, we will first briefly introduce RP's essence. In this section, we do not intent to cover each and every aspect of RP, nor the many subtleties revealed in the voluminous literature on resource-partitioning theory (for an overview, see Carroll, Dobrev and Swaminathan, 2002, or Boone and van Witteloostuijn, 2004). Rather, this section aims to review the core logic of the theory, as this will be the backbone of our EGT model presented below.

RP refers to the process where "under certain conditions, the resource space becomes partitioned into generalist and specialists segments" (Carroll, Dobrev and Swaminathan, 2001: 2). Indeed, many industries reveal two trends: increasing market concentration among large generalist organizations <u>and</u> resurgence of small specialist organizations. This is witnessed by the evidence for many mature industries in the late twentieth century (Carroll and Hannan, 2000a; Carroll et al., 2001). Resource-partitioning theory, developed by Carroll (1985) as a complement to Freeman and Hannan's (1983) niche width story, explains under which conditions this pair of trends occur simultaneously within the same industry, a combination once regarded to be very unlikely and highly implausible, being in contrast to standard theory in IO economics

(Sutton, 1991). Resource-partitioning theory, however, views the two trends as fundamentally interrelated.

The concepts of generalism and specialism come from bio-ecology, and were introduced by Hannan and Freeman (1977) as key notions in OE's niche width theory. According to niche width theory (Freeman and Hannan, 1983), the distinction between a generalist and a specialist organizational form refers to the variance in the organization's resource utilization. A generalist organization targets a wide range of environmental resources, or a wide niche, by providing an offer with broad appeal. By contrast, a specialist organization occupies a limited range of resources by producing an offer with narrow appeal. In bio-ecology, this relates to the extent to which a species is adapted to a broader or a narrower set of environmental conditions. In OE, generalist organizations are characterized by their broad fundamental niches[9] as their products attract people from very different taste groups, whereas specialists serve a narrow fundamental niche with an offer that focuses on specific tastes. The generalists' advantage is their broad and rich potential customer base. But because of their broad appeal, their offer cannot be as precisely tuned at the customers' wishes as that of specialists. This is in contrast with the sharply put stance of specialist organizations that can exploit their niche with high efficiency, collecting a high percentage of the clients from their narrower potential customer base.

In a RP context, the argument is that generalists are located in the market's center, and specialists in the market's periphery. The RP model describes how selection processes structure organizational populations when resources are unevenly distributed in

[9] Fundamental niches tend to be different from realized niches as a result of competition (Hannan et al., 2003b; Péli and Bruggeman, 2007).

the environment, forming a resource-abundant market center *vis-à-vis* a resource-scarce market periphery (Carroll, 1985; Carroll and Hannan, 2000b; Hannan et al., 2003a). This is RP's first key condition: the distribution of environmental resources features peak(s) and tails. Extant and potential consumers in a market are located across multiple dimensions, which might represent consumers' socio-economic or demographic characteristics. So, every firm is located in a niche in this multi-dimensional space (Carroll et al., 2001; Boone, Carroll and van Witteloostuijn, 2002). The second key condition is that generalist organizations located in the center can benefit from scale economies, whilst their specialist counterparts inhabiting peripheral niches cannot. Under this pair of conditions, RP theory renders three predictions (or theory components).[10]

First, in their struggle to survive, generalists will face crowding in the center of the resource space (Carroll and Hannan, 2000b). Because they seek to target a broader range of resources, generalists are more likely to occupy the market center. In contrast, specialists with a smaller range of resources can flexibly locate either in the market center to compete with generalist organizations or in periphery to avoid head-on conflict with the generalists. On the one hand, due to scale advantages, organizations targeting larger resource segments have lower unit costs than those serving smaller segments. A position in this lucrative center of the market offers the opportunity to grow and expand further (Carroll et al., 2001). The successful organizations become generalists, and grow large. On the other hand, smaller organizations meeting larger organizations in the market's center will eventually fail because of the formidable competition they face.

[10] This pair of conditions is essential. There is more to RP, though. For instance, two auxiliary assumptions are that the peaked resource space should feature a sufficient level of heterogeneity (Boone et al., 2002) and that consumers should be sufficiently mobile (García-Díaz and van Witteloostuijn, 2006). In the context of the current paper, for the sake of brevity, we ignore many of these and other subtleties.

Second, this generalist competition in the market center will trigger market concentration (Carroll and Hannan, 2000b). Generalist organizations engage in an ever-escalating contest for resources that can be converted into scale economies. As Carroll and Hannan (2000b: 263) argue, "[t]he most intense fighting occurs in the highest density or most abundant resource areas," which is in the market center. In the long run, larger organizations will outcompete their smaller opponents in the market center, because they are more capable to reap scale economies under the premise of increasing returns to scale. The survivors occupy adjacent regions left by their failed counterparts, and secure more free space. Eventually, they become larger, and ever more general. The growth and expansion of the surviving generalists and the demise of their failing opponents imply increasing market concentration. The larger scale economies are and the steeper the resource peak is, the more concentrated the market will be.

Third, specialists emerge and proliferate in the periphery (Carroll and Hannan, 2000b). For this to happen, two further conditions must be in place. For one, generalists cannot secure the entire free space because doing so would be too costly or would entail too much loss of original target area. Additionally, the so-called mechanism of competitive release (Hannan et al., 2003a) postulates that the demise of the failing organizations in or near the market center relaxes constraints on the market periphery. With this additional pair of conditions in place, the resurgence of specialists can materialize. Away from the market center, specialists can find viable locations where resources are spread thinly, implying that these are not attractive to the encroaching generalists (Carroll, 1985). The emergence of specialist organizations is associated with "entrepreneurs discovering and populating the residual resource space that lies outside the generalist areas" (Boone et al., 2002: 412). Due to market concentration in the center and competitive release in the periphery, the resource space available to specialists expands, leading to a rise in the viability of specialist organizations: "when these resources are sufficient to sustain a specialist segment, the market is 'partitioned' in that it appears that generalists and specialists organizations do not compete; they depend on the different parts of the resource base" (Carroll et al., 2001: 15).

AN EVOLUTIONARY GAME THEORY MODEL

Two-Fold Contribution

Carroll's (1985) original formulation of RP not only initiated an impressive series of empirical studies, but also triggered a much smaller number of theoretical refinements (see, e.g., Péli,1997; Péli and Nooteboom; 1999; Hannan et al., 2003a, 2003b; Hannan, Pólos and Carroll, 2004; Boone and van Witteloostuijn, 2004). None of these theoretical extensions used EGT, though, but rather formal logic, geometry or verbal argumentation. The current paper adds to this literature by introducing another new formal modeling tool in the study of RP (and OE more broadly, for that matter)—evolutionary game theory. EGT is particularly applicable to issues of RP and OE by offering a robust toolkit to study strategic interaction and behavioral change over time, revealing how macro outcomes result from micro interactions. In EGT, the outcome for each individual agent depends not only on the 'background' environment, but also on others' behavior and its own (Friedman, 1998). This very feature of EGT makes it well suited to explore micro-level processes driving the impact of both organizational (cf. the notion of biotic factors in bio-ecology—e.g., indirect competition and density dependence in OE) and environmental factors (similar to abiotic factors in bio-ecology—e.g., resource space and consumer audience in OE) on organizational and population viability.

Our EGT treatment of RP adds to the literature in two ways. First, as Hannan et al. (2003a) point out, the main constraint imposed in earlier treatments of RP is that the environment (i.e., the behavior of the audience) is set constant. However, RP processes may be influenced by changes in the environment. For instance, Péli and Nooteboom (1999) notice that a change in the number of relevant resource space dimensions—and hence in the resource space's geometry—merits future research, whereas Dobrev (2000) argues that RP processes may well be reversible if market concentration—for whatever reason—starts to decrease, rather than to increase. In the EGT model of RP presented below, we first study the impact of changes in the resource distribution on generalist and specialist organizational performance, on the one hand, and the market structure outcome, on the other hand.

Second, we focus on the effect of different types of scale economies. Boone and van Witteloostuijn (2004) and van Witteloostuijn and Boone (2006) argue how subtle differences in the nature of scale and scope economies may influence market structure outcomes. For instance, RP processes would be very different in nature if specialists could benefit from scope economies by spanning multiple peripheral niches. Our EGT treatment of RP adds another twist to this argument by distinguishing external from internal scale economies. To date, OE and RP have been limited to the study of the effect of internal scale economies—i.e., to the influence of increasing returns to scale as featured in the downward-sloping shape of an individual organization's cost function. In economics, external economies of scale are argued to operate at a higher level of analysis, next to and on top of internal scale economies: that is, clusters or groups of organizations may benefit from cost-reducing spillover effects (see, e.g., Krugman, 1995). With our EGT model, we will explore the effect of such external scale economies as well.

Model Set-Up

Conceive a market that has two generic organizational strategies, or forms: generalists and specialists, denoted by *G* and *S*, respectively. Following RP theory, a generalist is presumed to inherently prefer to operate in the market center and a specialist in the market's periphery, due to product offering characteristics or production technology features. In the market center, the group of generalist firms produces an array of homogeneous products regarded by consumers as perfect substitutes. In the market periphery, each specialist firm offers a different product within a very small range of variation on the dimension of interest. So, a specialist i's products are not only distinct from all the offerings of generalists, but also from those of all other specialists j (all $j \neq i$). This setting assures that generalist products appeal to the largest range of consumers in the center, whereas the specialist products cater for various idiosyncratic taste preferences in peripheral niches.

Total demand size, of market center and periphery together, is denoted by a. As pointed out by van Witteloostuijn et al. (2003), such a parameter a can be viewed as a proxy of organizational ecology's notion of carrying capacity. By Hannan and Carroll's (1992: 29) definition, carrying capacity refers to "the numbers (of firms) that can be sustained in a particular environment in isolation from other populations (that is, in the absence of competition and facilitation)." In the spirit of Péli and Nooteboom (1999), the current model partitions the total market *a* into two segments—market center and market periphery—by a parameter *h* ($h \geq 1$),[11] which stands for the extent of demand differentiation. Together, *a* and *h* define a single-peaked demand curve, or a unimodal resource distribution (Boone et al., 2002). An increase in *h* reflects an increase in demand differentiation in terms of consumer taste preferences, product quality and or any other relevant product feature. So *h* can also be interpreted as a proxy of Péli and Nooteboom's (1999) resource dimensionality notion, used here as a measure of resource heterogeneity. As shown in Figure 1, demand in market center for generalist products is the *1/h* share of the total market demand *a*, leaving a residual demand in the periphery for specialist products of *(1-1/h)a*.

[Insert Figure 1 about here]

As *h* goes up, consumer demand becomes more differentiated: e.g., the resource space extends into new dimensions, implying that demand will shift from generalist products to specialist ones. The reverse is true for a decreasing *h*. In the extreme case, when there is only one dimension (i.e., $h = 1$), say, residual demand for specialist offerings is zero. In this extreme case, there are usually no specialists operating in the market at all, like in typical shortage economies (Péli and Nooteboom, 1999).

Given the above demand structure, on the one hand, generalists compete in the market center for the homogeneous demand resources with a size of *a/h*. The center reflects, in essence, a standard oligopoly with product homogeneity in IO theory (van Witteloostuijn and Boone, 2006). On the other hand, since each specialist produces a

[11] Empirically, in an *N*-dimensional resource space, some mathematical transformation of *N* (e.g., $N^{\frac{1}{\alpha}}$, where *N* is the number of dimensions) could be considered as a measure of the *h* value.

distinct variety, each specialist firm operates as a (small) local monopoly within its limited own consumer range. So, rivalry in the periphery resembles the theory of monopolistic competition in IO economics (Boone and van Witteloostuijn, 2004). Assuming that all specialist firms have the same capability in exploring opportunities in the residual resource space open to them, peripheral demand will be equally allocated across all specialist organizations. Hence, each specialist firm's share of total demand is $(a - a/h)/N_S$, where N_S is the number of specialist firms (see Figure 1). This configuration in the market periphery is somewhat reminiscent of Hotelling's spatial-competition model in IO theory (Hotelling, 1929; Tirole, 1988).

Decision-making

As far as decision-making of generalists and specialists is concerned, we first apply classic game theory logic, by adopting two pieces of standard IO economics. All firms compete over quantity (in IO terminology, engage in Cournot competition) and face a standard linear downward-sloping demand function. Let P_G denote the price of the generalists' homogeneous products (since they are homogeneous, we identify them as a group, with a product G), Q_G total supply of all generalists, P_{S_i} the price of specialist i's product ($i = 1,\ldots,N_S$), N_S the number of specialist firms, and Q_{S_i} the output of specialist product S_i. Then, the generalist and specialist firms' inverse demand functions are

$$P_G = \frac{1}{h}a - Q_G \text{, and} \tag{5}$$

$$P_{S_i} = \frac{a}{N_S}(1 - \frac{1}{h}) - Q_{S_i} . \tag{6}$$

Note that the size of demand for the generalists' product is negatively correlated with resource dimensionality or differentiation h, whereas the demand size for specialist i's offering is increasing in h and decreasing in the number N_S of specialist firms.

Let N_G denote the number of generalist (G) firms, N the total number of firms (G and S, for specialist), and x the fraction of G firms, then $x = \frac{N_G}{N} = \frac{N_G}{N_G + N_S}$. In the market center, each generalist engages in N_G-firm Cournot competition. Each G firm select output q_G to maximize its profit. Assume that all generalists have identical cost curves, with an average cost of c_G. Then, in equilibrium, all G firms have identical output and profit levels. The simultaneous solution to the first-order conditions gives the symmetric equilibrium with an output and profit level (π_G) of, respectively,

$$q_G = \frac{\frac{a}{h} - c_G}{N_G + 1} = \frac{\frac{a}{h} - c_G}{xN + 1}, \text{ and}$$

(7)

$$\pi_G = \frac{(\frac{a}{h} - c_G)^2}{(N_G + 1)^2} = \frac{(\frac{a}{h} - c_G)^2}{(xN + 1)^2}. \tag{8}$$

For specialists, with the same assumptions of profit maximization and identical cost curves in place, the local (i.e., niche-specific) monopoly output (q_S) and profit (π_S) levels for each specialist firm are solved as

$$q_S = \frac{1}{2}[(1 - \frac{1}{h})\frac{a}{N_S} - c_S] = \frac{1}{2}[(1 - \frac{1}{h})\frac{a}{(1 - x)N} - c_S], \text{ and} \tag{9}$$

$$\pi_s = \frac{1}{4}[(1-\frac{1}{h})\frac{a}{N_s} - c_s]^2 = \frac{1}{4}[(1-\frac{1}{h})\frac{a}{(1-x)N} - c_s]^2 , \qquad (10)$$

where c_s is the identical average cost level for all specialist firms.

The above is an IO model of RP's dual market structure, with an oligopolistic core [Eqs (7) and (8)] and a periphery with monopolistic competition [Eqs (9) and (10)], following van Witteloostuijn and Boone (2006). Additionally, we introduce two different types of scale economies, reflecting the relative scale advantage of generalism *vis-à-vis* specialism: internal and external economies of scale. According to Marshall (1920) and Krugman (1995), internal economies are reflected in a fall in unit costs arising from the expansion of an individual firm's output level. In essence, such internal scale economies mirror the consequences of internal cost efficiency, or the so-called minimum efficient scale. External scale economies, in contrast, refer to the reduction in unit costs that is due to the expansion of the industry as a whole, rather than to an increase in the size of individual firms.

In line with RP theory, we assume that a generalist position is associated with increasing returns to internal scale, whereas specialist organizations face constant returns to internal scale. This setting implies that internal scale economies are present in the market center (reflected in a parameter e_{in}), but not in the market's periphery. Additionally, which is new to RP, we introduce external scale economies (through a parameter e_{ex}). Introducing this external scale parameter into the generalists' cost structure is reminiscent of Krugman's (1995: 1252) argument about industry-specific external economies, which maintains that, due to the presence of industry-specific external economies, "the efficiency of each atomistic firm is an increasing function of total industry output.” External economies may, for instance, be the result of shared resources, such as a joint labor market and knowledge infrastructure. This type of ‘agglomeration effect’ is assumed to work well in the market’s center, where similar generalist firms group together in a crowded space, but not in the periphery, where different specialist organizations are located apart in small isolated niches.

As shown in the Appendix, the production cost of generalism is $c_G = c_S - e_{in}q - e_{ex}Q_G \ (1 > e_{in} \geq 0 \ \text{ and} 1 > e_{ex} \geq 0)$, which indicates, due to the presence external and /or internal scale economies in the production of product *G*, that generalist firms have lower unit costs than their specialist counterparts. The larger the value of the parameters e_{in} or/and e_{ex}, the larger is the scale advantage in the generalist center, and hence the lower is the production cost of generalism *vis-à-vis* specialism. As above, a generalist position is associated with the output and profit

$$q_G = \frac{\frac{a}{h} - c_S}{(1-e_{ex})(N_G+1) - 2e_{in}} = \frac{\frac{a}{h} - c_S}{(1-e_{ex})(xN+1) - 2e_{in}}, \text{ and} \tag{11}$$

$$\pi_G = \frac{(1-e_{ex}-e_{in})(\frac{a}{h}-c_S)^2}{[(1-e_{ex})(N_G+1)-2e_{in}]^2} = \frac{(1-e_{ex}-e_{in})(\frac{a}{h}-c_S)^2}{[(1-e_{ex})(xN+1)-2e_{in}]^2}. \tag{12}$$

From Eqs (10) and (12), we learn that the profits of generalists and specialists are contingent upon firm density in each segment of the market (i.e., center and periphery), the consumers’ degree of differentiation *h*, total market demand size *a*, and the levels of unit cost in each organizational form’s cost function. Eq. (12) shows that the generalists’ profit is also contingent on the relative level of scale economies of the center *vis-à-vis* the periphery. Figure 2 graphs these short-run profits as a function of the fraction x of generalists.

[Insert Figure 2 about here]

On the one hand, the generalist profit curve is downward-sloping. As x goes up, the increasing number of generalists in the market center escalates competition, which drives profit down for each *G* firm. When the industry is full of generalists, profit is minimal. On the other hand, the specialist profit curve is upward-sloping. The increase in x implies lower specialist density because the environment is becoming less favorable to specialists due to increasing competition from higher numbers of generalists. The exit of specialists does release free resource space for those specialists that are still able to protect their peripheral niches. As a result, the surviving specialists, though lower in number, become more profitable. Eventually, one or few local monopolists will occupy the entire periphery, earning monopoly profits.

This scenario resembles the outcome of *n*-firm Cournot dual market competition with a homogeneous product core and a differentiated product fringe within the framework of IO (Sutton, 1991). In such an IO framework, the numbers of generalist and specialist firms are endogenously determined by the demand and cost structures in each sub-market, core (center) and fringe (periphery), provided that free entry and exit are assumed. Then, equilibrium in each of both segments of the market is not directly affected by the outcome in the other segment. It is clear that such a framework, which basically reflects two pieces of standard game theory (i.e., Cournot oligopoly in the center and monopolistic competition in the periphery), says nothing about the story of resource partitioning. Next, we will therefore move beyond this rather static imaginary by developing an EGT analysis of the above set-up.

Replicator dynamics and evolutionary equilibria, again

Based on the intuitive notion behind the replicator dynamics (RD) tool, arguing that the fitter strategy at any moment is more likely to be employed in the next time period, we conceive a story of an EGT version of an RP game as follows. There are two distinct types of players in the market: potential entrants and existing incumbents. At any point in time, potential entrants decide on their *ex post* market entry postures in the next period (say, t+1) depending on the observed *ex ante* profit differential (in t) between the two organizational forms, or strategies; similarly, existing incumbents select their successive market postures in the next period based on the observed profitability difference. That is, if generalism is more profitable in t than specialism, potential entrants will adopt generalism as their actual market posture in the next operational period t+1, whilst existing incumbents will stick to the generalist strategy, switch to generalism from specialism, or will exit from the market altogether in the successive operational period t+1.

So here we adopt a key assumption from IO (i.e., Cournot competition): in each operational period, the active players maximize expected profit by simultaneously choosing output. Thus, in this baseline setting, micro-level decision-making follows the standard IO tradition. From there, though, we model the dynamics by applying evolutionary game theory. By and large, the sources of dynamics can be entry and exit and / or organizational change and repositioning, all driven or motivated by firm-level responses to environmental threats and opportunities. This implies that the two conflicting perspectives on the key mechanism driving population-level change—the adaptionist and selectionist views—are combined here. The adaptationist perspective (Cyert and March , 1963; Child, 1972) emphasizes the role of micro-level agent adaptation, whereas the selectionist view (Hannan and Freeman, 1977, 1984) argues that selection processes at the macro population level reflect the dominant force. In our EGT frame, exit and entry are the consequences of macro-level selection, while organizational repositioning is the result of micro-level adaptation.

In essence, much of the dynamics is driven by entrepreneurial discovery processes, a terminology central to the conception of market processes in modern Austrian economics. That is, higher profit in a certain niche or segment of the market induces entrepreneurship flowing into this niche or segment through entry or repositioning, implying that niche or segment-specific firm densities change accordingly. The entrepreneur discovery theory (von Mises, 1949; Kirzner, 1992, 1997) views the market as an entrepreneurially driven profit-seeking process. As Kirzner (1997: 70) argues, "[e]ach market is characterized by opportunities for pure entrepreneurial profit (created by earlier entrepreneurial errors). … The daring, alert entrepreneur discovers these earlier errors, buys where prices are 'too low' and sells where prices are 'too high'. In this way, … price discrepancies are narrowed in the equilibrative direction." So, in the Austrian tradition, equilibrating processes are key, and not equilibrium states (that tend to be never reached anyway, given the moving target nature of such imaginaries). This Austrian theory of entrepreneurial discovery is similar to the micro-level logic underlying EGT, particularly the RD and EE tools.

In an EGT context, the profit of a firm reflects the fitness of the strategy that is currently used by this firm. Let $f(G)$ and $f(S)$ denote fitness of generalism and specialism, respectively, and $\overline{f}(x,t)$ the average fitness of the population as a whole at time point t with $x(t)$ being the share of generalists and $1 - x(t)$ the share of specialists. Then, we have

$$f(G) = \pi_G,$$

$$f(S) = \pi_S, \text{ and}$$

$$\overline{f}(x,t) = x(t)f(G) + (1 - x(t))f(S) = x(t)\pi_G + (1 - x(t))\pi_S.$$

After substitution this above set of three equations into Eq. (4), we have a formula for the dynamic behavior of the generalist firms:

$$\frac{dx(t)}{dt} = x(t)(1 - x(t))(\pi_G - \pi_S). \tag{13}$$

The evolutionary equilibrium (EE) is the share x^* where the G and S strategies are equally fit—i.e., equally profitable. Then, the profit difference $\pi_G - \pi_S$ defines the change rate of generalism at zero in x^*. Out of equilibrium, this change rate is a monotonically decreasing function of x in $(0, x^*)$ and a monotonically increasing function of x in $(x^*, 1]$. As illustrated in Figure 2, if we start from a state at any point in time below the EE share x^*, say x_1, then G firms are more profitable than the S strategies. Under the RD assumption, there will be net entry / repositioning into the generalist center and net exit / repositioning out of the specialist periphery in the next period. Increasing generalist net entry / repositioning will lower profitability in the market center, whilst specialist net exit / repositioning will drive up profitability in the market's periphery. This change process proceeds one period after the other until the EE share x^* is reached, where neither form is more profitable than the other. Similarly, in a state above x^*, say x_2, the opposite change dynamics will move the system to x^*.

Thus, the equal profit share x^*, which can be either an interior or a corner solution, is the unique evolutionary equilibrium (EE). In other words, in the long run, we can always find a stable mixture of *G* firms (with a fraction of x^*; $x^* \in [0,1]$) and *S* firms (with a fraction of $1 - x^*$) in this market. In our model, moreover, the EE is not only locally asymptotical stable, but also globally stable. Given the dynamics implied by Eq. (13), there exists only one stationary state x^*, because the profit of generalists (specialists) is a decreasing (increasing) function of x. For $0 < x < x^*$, we have $\pi_G(x) > \pi_S(x)$, so that $\frac{dx}{dt} > 0$. For $x^* < x < 1$, we have $\pi_G(x) < \pi_S(x)$—hence $\frac{dx}{dt} < 0$. Therefore, any perturbation from the steady state x^*, however large or small, will trigger a return to x^*.

Before moving to the further analysis of our EGT model of RP, two comments are worth making. First, as we argued above, the entrepreneurial discovery process plays a significant role in driving the step-by-step move to the evolutionary equilibrium. In a similar vein, Novshek and Sonnenschein (1987), assuming that entrepreneurship is a fixed production factor (similar to capital and labor), suggest that with free entry and exit this entrepreneurial production factor will trigger positional changes such that a long-run dynamic equilibrium will be reached, *ceteris paribus*, in which all firms earn zero profits. In the Novshek and Sonnenschein's framework, perfect competition operates in a market where all firms are relatively small. In our setting, firms are not necessarily small relative to the market, and thus is the zero-profit outcome not essential—in equilibrium, all that matters are equal profits across strategies, however large or small.[12] The absolute equilibrium profit level is determined by inertia-related forces, such as entry and repositioning (sunk) costs. We return to this issue in the Appraisal.

Second, our EGT model can be interpreted from a "playing the field" perspective as well —i.e., then all players are interacting together, rather than being engaged in sequential pair-wise contests. In this case, the payoff of an individual firm is not determined in a series of pair-wise contests, but rather by a competitive game in which her own strategy plays against the aggregated strategy of the population as a whole. As van der Laan and Tieman (1996) maintain, the replicator dynamics and evolutionary equilibrium toolkit can still be applied in this "playing the field" case.

The Effect of Changes in the Resource Distribution

A key condition of RP is the peaked shape of the resource distribution. With our EGT model, we can explore this issue analytically. As the demand or resource heterogeneity parameter h changes from its minimum (h = 1) to its maximum value, the consumers' taste preferences become more and more elaborated. As a consequence, the profit curve of generalists shifts downward, whereas that of specialists shifts upward. This is visualized in Figure (3a).

[Insert Figure 3 about here]

[12] Note, by the way, that economics' profit concept does include a positive compensation for all factors of production—interest for capital, wages for labor, and 'rents' for entrepreneurs. This is why, strictly speaking, the traditional zero-profit outcome in much economics refers to what is coined zero economic profit.

Eventually, with *h* increasing, the unique evolutionary stable equilibrium is reached at point $x^* = 0$. With $x^* = 0$, all generalists are out of business, selected out in an environment of resource heterogeneity that favors specialism, either by exit of generalists or by generalists changing into specialists. The maximum value of *h* corresponds to the "flat" resource distribution case in Boone and van Witteloostuijn's (2006) framework—that is, there is no peak or market center, as resources are distributed equally across space. This case might be found in a highly mature market where consumer preferences over product characteristics are extraordinarily diversified, or in a young industry in which consumer tastes have not yet crystallized around a certain average taste.

The reverse holds true when *h* decreases from its maximum to its minimum value ($h = 1$)—then, $x^* = 1$ is the unique evolutionary stable equilibrium. This case is represented by Figure (3b). Now, all firms eventually adopt the generalist form because the consumers in the market reveal only very simple preferences for homogeneous product characteristics—only price matters. Put differently, the resource space reflects just a single one-dimensional peak. For example, in a shortage economy, people's demand for food is most likely to be one-dimensional, and so was demand for cars in the early automobile industry. In both corner solution cases, complete dominance of a pure strategy, either the generalist or the specialist stance, is the evolutionary equilibrium. When *h* is somewhere in between its minimum value 1 and the maximum, a mixed outcome emerges as the EE. Then, the coexistence of generalism and specialism is the unique evolutionary equilibrium.

Proposition 1*: As the resource distribution shifts from homogeneous to heterogeneous (i.e., from* $h = 1$ *to* h*'s maximum value), the viability of generalists decreases, which is reflected in a decline of the share of generalists in population density (* x^* *falls down). Generalism is doomed to extinction if the resource space reflects extreme heterogeneity (if* h *is at its maximum,* $x^* = 0$*). Conversely, as the resource distribution shifts from heterogeneous to homogeneous (i.e., from its maximum value to* $h = 1$*), the viability of specialists declines, which is reflected in a fall in the share of specialists in population density (*x^* *goes up). Specialism is doomed to extinction if the resource space features extreme homogeneity (if* $h = 1$*, then* $1 - x^* = 0$*).*

Proposition 1 is in line with a standard RP insight (Carroll et al., 2001): a necessary condition for RP to emerge is that the resource space features a peak-tail distribution (i.e., in-between values of h). So, our EGT model provides a micro-foundation of RP, showing how a macro-level RP insight is consistent with an IO-type of EGT model of micro-level interaction (cf. van Witteloostuijn et al., 2003). Moreover, similarly, both corner cases with h at its minimum and maximum value offer EGT support for the extreme resource homogeneity and heterogeneity cases, respectively, as described by Boone and van Witteloostuijn (2006). Finally, note that the analytical precision of our EGT imaginary of RP offers the opportunity to calculate the evolutionary stable densities (through the fraction x^*) of generalist and specialist organizations, *ceteris paribus*.

The Effects of Scale Economies and Competitive Release

Above, we merely illustrated how EGT can be applied to develop an analytical model of RP, based on EGT's toolkit for modeling evolutionary micro-level interaction. Next, we extend extant RP theory by adding another feature to the model: the distinction between external and internal scale economies. To analyze the effect of both types of scale economies, we take the partial derivatives of the generalist profit function with respect to the internal and external scale economies parameters. This gives

$$\frac{\partial \pi_G}{\partial e_{in}} = (\frac{a}{h} - c_S)^2 \frac{-(N_G - 3)(1 - e_{ex}) - 2e_{in}}{[(N_G + 1)(1 - e_{ex}) - 2e_{in}]^3} < 0 \text{ for } N_G \geq 3, \tag{15a}$$

$$\frac{\partial \pi_G}{\partial e_{in}} > 0 \text{ for } N_G < 3, \text{ and} \tag{15b}$$

$$\frac{\partial \pi_G}{\partial e_{ex}} = (\frac{a}{h} - c_S)^2 \frac{(N_G + 1)(1 - e_{ex} - 2e_{in}) + 2e_{in}}{[(N_G + 1)(1 - e_{ex}) - 2e_{in}]^3} > 0 \text{ for } N_G > \frac{-2e_{in}}{1 - e_{ex} - 2e_{in}} - 1. \tag{16}$$

Inequalities (15a/b), on the one hand, imply that the increase in the internal scale advantage parameter almost always leads to decreased generalist profitability. The exception confirming this rule, reflected in Eq. (15b), is the case of a very concentrated market structure—i.e., the duopoly and monopoly market. Inequality (16), on the other hand, reveals that the threshold level of e_{ex} is very small: thus, the condition for N is always satisfied. Therefore, we conclude that external scale advantage of generalists (in the center) *vis-à-vis* specialists (in the periphery) always leads to an increase in generalist profitability. These outcomes imply that the effect of internal scale economies contrasts sharply with that of external economies in non-extremely concentrated industries.

In an industry with more than two firms, as the e_{ex} increases (or e_{in} decreases), the generalist profit curve shifts up, as is visualized in Figure (4a).

[Insert Figure 4 about here]

This means that larger external scale advantages in the generalist center facilitate higher generalist profitability, which attracts net entry into the generalist core and net exit from the specialist fringe. This, in turn, drives up specialist profits, too, since fewer and fewer specialists remain in business. Eventually, the evolutionary equilibrium is realized at state x^* in which the fraction of generalists has gone up. Conversely, a fall in external scale economies (or an increase in internal scale advantages) in the market center implies that the generalist profit curve shifts downward. Moreover, specialist profitability will decrease as well, as a consequence of net entry into the specialist periphery. The new evolutionary equilibrium is reached at state x^*, where the proportion of generalists has declined. This is revealed in Figure (4b). In a duopoly or monopoly market, however, different processes will occur: both increased center external and internal scale advantages enhance the profitability of generalists.

The above arguments are summarized in Propositions 2 and 3.

Proposition 2: *(a) In a non-extremely concentrated industry ($N_G \geq 3$), if external scale advantages in the industry center shift from low (high) to high (low), the EE fraction* x^* *of generalists increases (declines); (b) In a non-extremely concentrated industry ($N_G \geq 3$), if internal scale advantages in the industry center shift from low (high) to high (low), the EE fraction* x^* *of generalists declines (increases).*

Proposition 3: *In an extremely concentrated industry ($N_G < 3$), if external or internal scale advantages in the industry center shift from low (high) to high (low), the EE level of generalist profitability increases (declines).*

The result with respect to the effect of increased generalist internal scale advantages fits well with RP theory. Because of abundant resources available in the center of the market, internal scale advantages can be reaped. This triggers increases in generalists' production volumes, implying aggressive Cournot competition that is associated with a sharp decline in the price for the generalist offering. This escalation of competition in the center of the market implies the viability of only a few generalists (and, thus, increasing generalist concentration). As a consequence, the "survival chances" of specialists, operating at the periphery of the resource space, increase, triggering net entry into niches (and, hence, increasing specialist density).

The result with respect to generalist external scale advantages in the market center suggests that the ability and willingness to build positive externalities (through, e.g., common infrastructures and networks) in a strongly competitive environment has a clear effect on the evolutionary stable state. Such external scale economies improve the profitability of generalist and specialist organizations, and hence enhance the viability of the population as a whole, not only in the center but also in the periphery: profitability goes up across the board, also in peripheral niches due to the net exit effect. Examples may be the early infancy phases of the automobile and ICT industries. At that time, the enhanced external scale economies via, say, improvement in infrastructure helped the organizational population as a whole to increase viability.

Concentration of Generalists and Competitive Release

Our Proposition 1, although relating to behavior of both generalists and specialists, merely tells the first part of the resource-partitioning story. That is, generalists start to crowd and compete in the market center more and more as the resource space shifts more and more toward a unimodal shape (or, in our EGT context, as h more and more decreases toward its minimum value 1, implying less and less differentiated demand). In this section, to close the circle, we make the EGT version of the second part of the RP story explicit: how does concentration of generalists and proliferation of specialists come about in our EGT model in a peaked resource space?

Below, we construct an EGT story of generalist concentration and competitive release with the aid of Figure 5.

[Insert Figure 5 about here]

Key is to disentangle the resource space from the scale advantage effect. On the one hand, a lower value of the resource heterogeneity parameter h drives up profit of generalists: thus, the generalist profit curve shifts upward from the G to the G' curve. The evolutionary equilibrium is located at share state x_1, *ceteris paribus*, implying a larger generalist fraction. On the other hand, increased internal scale advantages have the opposite effect. In our EGT model, the resource heterogeneity parameter h and the internal scale economies parameter e_{in} are inherently correlated. As h declines, the resource space becomes more homogeneous: hence, more internal economies of scale can be reaped, implying that the parameter e_{in} will increase. This triggers aggressive scale-seeking Cournot competition in the generalist center, which leads to lower profitability for generalists. Decreased profitability in combination with increased scale results in a reduced number of generalists. The end result is increased concentration among generalist organizations in the market center. The movement along the *G'* curve from E_1 towards E_2 reflects this process of rising concentration.

The next step in the RP story relates to competitive release. That is, increased concentration in the center frees resources in the periphery, which creates opportunities for specialists. The demise of generalists (due to concentration) in the market center removes a powerful competitive constraint on specialists in the periphery (Hannan et al., 2003a). In our current EGT interpretation, concentration among generalists implies that specialist profitability increases, too: as a result, the specialist *S* profit curve shifts upward to the *S'* curve. The evolutionary equilibrium is eventually realized at state x_2*, by moving back from the would-be EE x_1. So, the proportion of specialist firms is greater in the actual equilibrium x_2* than in the would-be equilibrium x_1, which implies specialist proliferation.

APPRAISAL

Micro Rationality *vis-à-vis* Macro Selection

In this paper, we illustrated how EGT can be applied to OE issues. Our key claim is that EGT, by sharing OE's emphasis on evolutionary processes, offers a toolkit that can be instrumental in developing a complementary analytical theory-building approach in OE, next to formal logic, standard game theory and agent-based simulation. As the proof of the pudding is in the eating, we presented an EGT model of RP, a well-established theory fragment in OE. In so doing, we offered three substantive contributions to RP. First, we showed how our EGT model offers a micro-foundation for macro-level RP outcomes.

That is, in our EGT model, RP processes emerged from the micro-level interaction among individual profit-seeking organizations. Second, we demonstrated how this EGT model of RP can be used to analyze with greater precision the conditions underlying RP. Particularly, we revealed how the shape of the resource space, reflecting more or less demand differentiation, determines the market structure outcome, favoring generalists, specialists, or both. Third, we extended RP by adding a new feature: external scale economies, next to internal scale advantages. Calculating the evolutionary equilibrium, we offered proof for the differential effect of both types of scale economies.

By applying EGT, we touch upon a fundamental issue: the role of individual rationality *vis-à-vis* environmental selection. Strictly speaking, being a tool developed in bio-ecology, individual rationality is not a 'natural' component of EGT. However, in the context of applications to organizations competing in markets, IO economists have added maximizing decision-making behavior to the EGT apparatus. Above, we adopted a similar approach by assuming an entrepreneurial profit-seeking process. So, a central issue is how EGT relates to the neoclassical assumption of agent rationality, or profit maximization in our context of inter-firm competition. Tirole (1988: 261) argues that "[t]he evolutionary approach goes all the way (as the rational approach) but not requiring maximizing behavior at all." But how can this be reconciled with firm-level profit-maximization decision-making that dominates so much IO-inspired EGT? To solve this paradox, we need first to make clear what is being maximized in the current context of our EGT model of OE (and RP, for that matter).

By and large, selection is viewed as an optimization process in EGT (Hofbauer and Sigmund, 1992). Similarly, Hannan and Freeman (1977: 939-940) state clearly that “[f]rom a population ecology perspective, it is the environment which optimizes … If there is a rationality involved, it is the ‘rationality’ of natural selection.” However, they also recognize that “[o]rganizational rationality and environmental rationality may coincide in the instance of firms in competitive markets. In this case, the optimal behavior of each firm is to maximize profit and the rule used by the environment (market, in this case) is to select out profit maximizers.” Keeping these arguments in mind, we can revisit Figure 2. In this figure, the profit curves can be regarded as the net consequence of the optimizing forces of the macro-level environmental selection <u>and</u> micro-level organizational decision-making. Along the vertical axis, profit π represents the outcome of the individual maximizing behavior; along the horizontal axis, share x reflects the outcome of environmental selection.

The key is that, as Vega-Redondo (1996: 35) argue, “if survival is linked to differential profits, a firm which lives in a competitive industry will only survive by being competitive” (cf. Friedman and Fung, 1996). However, decision-making on the basis of observed profit differences may well be boundedly rational, due to the lack of foresight as to the long-run consequences of different decisions. On the one hand, out-of-equilibrium behavior is boundedly rational, as firms decide to enter into and reposition toward niches that are still on the move. That is, the out-of-equilibrium profit differential will prove not to be sustainable. On the other hand, in equilibrium, the agents’ behavior will emerge as rational, as now profit differences are zero by the very definition of the evolutionary equilibrium concept. All this is, of course, *ceteris paribus*. If, for whatever reason, the current EE collapses, the system will enter into a new phase of evolutionary dynamics. This is precisely the fundamental argument underlying the neo-Austrian entrepreneurial discovery theory: for a wide variety of reasons, the would-be equilibrium state is a moving target, implying that profit-seeking rather than profit-maximizing decision-making drives entrepreneurial behavior. In our RP setting, it may be that the shape of the resource space or the nature of scale economies changes over time, triggering renewed ecological processes.

Future research issues

We believe that the application of OE offers ample opportunities in the OE domain. By way of conclusion, therefore, we would like to point to two examples of future research lines. First, the rules of the segment-specific competitive games can be modeled differently to analytically study different market forms, as suggested by van Witteloostuijn and Boone (2006). In our model, we assume that the products in the generalist center of the market are perfectly homogeneous, whilst the products in specialist periphery feature perfect heterogeneity. In so doing, we model a Cournot oligopoly generalist core that is only indirectly connected to a monopolistically competitive specialist fringe. However, introducing (imperfect) product substitution across the core and periphery, especially between generalist and specialist products, would affect the profit curves, and hence the nature of the equilibrium, as would introducing product heterogeneity in the core or imperfect substitution in the fringe. Similarly, scope economies can be introduced, implying the opportunity to cost-efficiently produce a portfolio of products that span across different niches. In a setting like this, issues of firm-level diversification and differentiation can be analyzed.

Second, different types of cost can be introduced. Particularly interesting, apart from economies of scope, would be to add a positive cost of entry or repositioning to our EGT model. On the one hand, a positive repositioning cost would introduce organization-level inertia. OE's inertia theory provides a series of reasons as to why organization can be expected to be inert, and why inert organizations are more likely to survive (Hannan and Freeman, 1984; Hannan, Pólos and Carroll, 2003a, 2003b, 2004). In our profit-seeking model of firm-level decision-making, such a positive repositioning cost would introduce a barrier to change. On the other hand, a positive entry cost would introduce population-level inertia. Free entry and exit favors selection processes (Baumol, Panzar and Willig, 1982). If entry and exit are costly, selection is hampered, as such a cost would deter entry and block exit. With both types of cost in place in our EGT model, we could analytically explore the relative importance of adaptation and selection under different sets of conditions.

REFERENCES

Alchian, A. 1950. Uncertainty, evolution and economic theory, *Journal of Political Economy*, 58: 211-222.

Axelrod, R. 1981. The emergence of cooperation among egoists. *American Political Science Review*, 28: 1-12.

Baumol, W. J., Panzar, J. C. and Willig, R. D. 1982. *Contestable Markets and the Theory of Market Structure*. New York: Brace Harcourt Jovanovich.

Boone, C., Carroll, G. R. and Witteloostuijn, A. van. 2002. Resource distribution and market partitioning: Dutch daily newspapers, 1968 to 1994. *American Sociological Review*, 67: 408-431.

Boone, C. and Witteloostuijn, A. van. 2004. A unified theory of market partitioning: An integration of resource-partitioning and sunk cost theories. *Industrial and Corporate Change*, 13: 701-726.

Carroll, G. R. 1985. Concentration and specialization: Dynamics of niche width in populations of organizations. *American Journal of Sociology*, 90: 1262-1283.

Carroll, G. R., Dobrev, S. and Swaminathan A. 2001. Resource partitioning among organizations in a market. Posted on August, 2001, at http://faculty-gsb.stanford.edu/nagymaros/working.htm.

Carroll, G. R., Dobrev, S. and Swaminathan A. 2002. Organizational processes of resource partitioning. In Kramer, R. and Staw, B. (Eds), *Research in Organizational Behavior*. Pp. 1-40. New York: JAI Press.

Carroll, G. R. and Hannan M. T. 2000a. Resource partitioning. Pp. 261-274 in *The Demography of Corporations and Industries*. Princeton, NJ: Princeton University Press.

Carroll, G. R. and Hannan, M. T. 2000b. *The Demography of Corporations and Industries*. Princeton, NJ: Princeton University Press.

Chiang, Y.-S. 2007. The evolution of fairness in the ultimatum game. *Journal of Mathematical Sociology*, 31: 175-186.

Child, J. 1972. Organization structure, environment and performance: The role of strategic choice. *Sociology*, 6: 1-22.

Cyert, R. M. and March, J. G. 1963. *A Behavioral Theory of the Firm*. Englewood Cliffs, NJ: Prentice Hall.

Dobrev, S. D. 2000. Decreasing concentration and reversibility of the resource-partitioning model: Supply shortages and deregulation in the Bulgarian newspaper industry, 1987-1992. *Organization Studies*, 21: 383-404.

García-Díaz, C. and Witteloostuijn, A. van. 2007. Co-evolutionary market dynamics in a peaked resource space. In: Bruun, C. (Ed.), *Advances in Artificial Economics: The economy as a complex dynamic system*. *Lecture Notes in Economics and Mathematical Systems*, 584. Pp. 94-104. Berlin: Springer Verlag.

García-Díaz, C., Witteloostuijn, A. van and Péli, G. 2008. Market dimensionality and the proliferation of small-scale firms: An agent-based modeling simulation, *Advances in Complex Systems*, 11: 231-247.

Fisher, R. A. 1930. *The Genetical Theory of Natural Selection*. London: Clarendon Press.

Freeman, J. and Hannan, M. T. 1983. Niche width and the dynamics of organizational populations. *American Journal of Sociology,* 82: 929-964.

Friedman, M. 1953. *Essays in Positive Economics.* Chicago: University of Chicago Press.

Friedman, D. 1991. Evolutionary games in economics. *Econometrica*, 59: 637-666.

Friedman, D. 1998. On economic applications of evolutionary game theory. *Journal of Evolutionary Economics*, 8: 15-43.

Friedman, D. and Fung, K. C. 1996. International trade and the internal organization of firms: An evolutionary approach. *Journal of International Economics*, 41: 113-117.

Fudenberg, D. and Tirole, J. 1991. *Game Theory*. Cambridge, MA: MIT Press.

Hamilton, W. D. 1967. Extraordinary sex ratios. *Science,* 156: 477-488.

Hannan, M. T. and Carroll, G. R. 1992. *Dynamics of Organizational Populations: Density, legitimation and competition*. New York: Oxford University Press.

Hannan, M. T., Carroll, G. R. and Pólos, L. 2003a. A formal theory of resource partitioning. Posted on May 6, 2003, at http://faculty-gsb.stanford.edu/nagymaros/working.htm.

Hannan, M. T., Carroll, G. R. and Pólos, L. 2003b. The organizational niche. *Sociological Theory*, 21: 309-340.

Hannan, M. T. and Freeman, J. 1977. The population ecology of organizations. *American Journal of Sociology,* 82: 926-964.

Hannan, M. T. and Freeman, J. 1984. Structural inertia and organizational change. *American Sociological Review*, 49: 149-164.

Hannan, M. T. and Freeman, J. 1989. *Organizational Ecology*. Cambridge, MA: Harvard University Press.

Hannan, M. T., Pólos, L. and Carroll, G. R. 2003a. Cascading organizational change. *Organization Science*, 14: 463-482.

Hannan, M. T., Pólos, L. and Carroll, G. R. 2003b. The fog of change: Opacity and asperity in organizations. *Administrative Science Quarterly*, 48: 399-432.

Hannan, M. T., Pólos, L. and Carroll, G. R. 2004. The evolution of organizational inertia. *Industrial and Corporate Change*, 13: 213-242.

Hannan, M. T., Pólos, L. and Carroll, G. R. 2007. *Logics of Organization Theory: Audiences, codes and ecologies*. Princeton, NJ: Princeton University Press.

Hofbauer, J. and Sigmund, K. 1992. Game dynamics. Pp 124-137 in *The Theory of Evolution and Dynamical Systems*. Cambridge: Cambridge University Press.

Hopkins, E. 1997. Evolving game theory. *Journal of Economic Surveys*, 11: 101-106.

Hotteling, H. 1929. Stability in competition. *Economic Journal*, 39: 41-57.

Kirzner, I. M. 1992. *The Meaning of Market Process: Essays in the development of modern Austrian economics.* London and New York: Routledge.

Kirzner, I. M. 1997. Entrepreneurial discovery and the competitive market process: An Austrian approach. *Journal of Economic Literature*, 35: 60-85.

Krugman, P. 1995. Increasing returns, imperfect competition and the positive theory of international trade. In Grossman, G. and Rogoff, K. (Eds), *Handbook of International Economics* (Volume 3). Pp. 1243-1277. Amsterdam: Elsevier.

Laan, van der G. and Tieman, X. 1996. Evolutionary game theory and the modeling of economic behavior. *Tinbergen Institute Discussion Paper 98-124/1*, Rotterdam: Tinbergen Institute.

Malthus, T. R. 1798. *An Essay on Population*. London: Johnson.

Marshall, A. 1920. *Principles of Economics* (1961, 9th edition). London: Macmillan.

Maynard Smith, J. 1982. *Evolution and the Theory of Games*. Cambridge: Cambridge University Press.

Maynard Smith, J. and Price, G. R. 1973. The logic of animal conflict. *Nature*, 246: 15-18.

McGraw, J. B. and Caswell, H. 1996. Estimation of individual fitness from life history data. *The American Naturalist,* 147 (1): 47-64.

Mises, L. von. 1949. *Human Action: A treatise on economics*. New Haven, CT: Yale University Press.

Novshek, W. and Sonnenschein, H. 1987. General equilibrium with free entry: A synthetic approach to the theory of perfect competition. *Journal of Economic Literature*, 25: 1281-1306.

Parayre, R. and Hurry, D. 2001. Corporate investment and strategic stability in hypercompetition. *Managerial and Decision Economics*, 22: 281-298.

Péli, G. 1997. The niche hiker's guide to population ecology: A logical reconstruction of organizational ecology's niche theory. *Sociological Methodology*, 27: 1-46.

Péli, G. and Bruggeman, J. 2007. The cricket and the ant: Organizational trade-offs in changing environments. *Journal of Mathematical Sociology*, 31: 205-235.

Péli, G. and Nooteboom, B. 1999. Market partitioning and the geometry of the resource space. *American Journal of Sociology*, 104: 1132-1153.

Rhode, P. and Stegeman, M. 2001. Non-Nash equilibria of Darwinian dynamics with applications to duopoly. *Internal Journal of Industrial Organization*, 19: 415-453.

Ruef, M. 2004. For whom the bell tolls: Ecological perspectives on industrial decline and resurgence. *Industrial and Corporate Change*, 13: 61-89.

Samuelson, L. 1997. *Evolutionary Games and Equilibrium Selection.* Cambridge, MA: MIT Press.

Schumpeter, J. A. 1943. *Capitalism, Socialism and Democracy*. London: George Allen and Unwin.

Sutton, J. 1991. *Sunk Cost and Market Structure: Price competition, advertising, and the evolution of concentration*. Cambridge, MA: MIT Press.

Taylor, P. D. and Jonker, L. B. 1978. Evolutionary stable strategies and game dynamics. *Mathematical Biosciences*, 40: 145-156.

Tirole, J. 1988. *The Theory of Industrial Organization*. Cambridge, MA: MIT Press.

Vega-Redondo, F. 1996. *Evolution, Games, and Economic Behavior*. New York: Oxford University Press.

Vickers, J. 1985. Delegation and the theory of the firm. *Economic Journal*, 95: 138-147.

Young, P. 1993. The evolution of conventions. *Econometrica*, 61: 57-84.

Weibull, J. W. 1992. An introduction to evolutionary game theory. *Working paper # 347*, Stockholm: The Industrial Institution for Economic and Social Research.

Weibull, J. W. 1997. What have we learned from evolutionary game theory so far? *Working paper # 487*, Stockholm: The Industrial Institution for Economic and Social Research.

Witteloostuijn, van A. 2002. Interorganizational Economics. In Baum, J. A. C. (Ed.), *Companion to Organizations*. Pp. 686-712. Oxford: Blackwell Publishers.

Witteloostuijn, van A. and Boone, C. 2006. A resource-based theory of market structure and organizational form. *Academy of Management Review*, 31: 409-426.

Witteloostuijn, van A., Boone, C. and Lier, van A. 2003. Toward a game theory of organizational ecology: Production adjustment costs and managerial growth preferences. *Strategic Organization*, 1: 259-300.

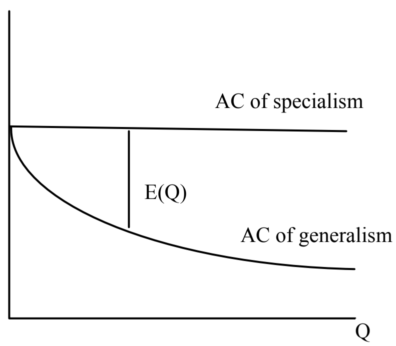
Witteloostuijn, A. van and Lier, A. van. 1990. Chaotic patterns in Cournot competition. *Metroeconomica: An international review of economics*, 41: 161-185.

Witteloostuijn, A. van and Maks, J. A. H. 1990. Walras on temporary equilibrium and dynamics. *History of Political Economy*, 22: 223-237.

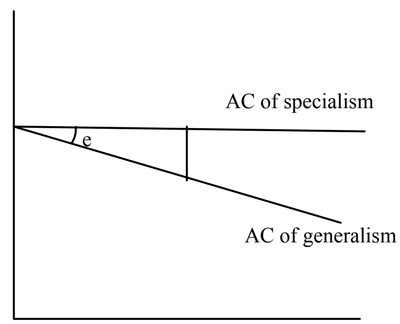
Zhang, J. 2004. A dynamic model of residential segregation. *Journal of Mathematical Sociology*, 28: 147-170.

APPENDIX: Parameterizing scale economies

Assume that generalism is associated with increasing returns to scale and specialism with constant returns to scale. Let $C(q)$ denote a firm's total cost function for producing output q. The shapes of average cost (AC) curves of generalists and specialists are visualized in Figure (A1), which is familiar from microeconomics textbooks. For generalists, for all q_1 and q_2 such that $q_1 < q_2$, average cost is decreasing: $C(q_2)/q_2 < C(q_1)/q_1$. For specialists, for all q_1 and q_2 such that $q_1 < q_2$, average cost is constant: $C(q_2)/q_2 = C(q_1)/q_1$.



A1



A2

Let $E(q)$ denote the cost difference of producing output q between the two organizational forms: $E(q) = C_S(q) - C_G(q)$. Clearly, $E(q)$ is increasing in q. For the sake of convenience, assume that the cost function of generalists is linear. Hence, as illustrated in Figure (A2), $E(q) = e_{in}q$, where the newly introduced parameter e_{in} reflects the slope of the linear AC curve of generalism, capturing the relative level of internal scale advantages of generalists *vis-à-vis* specialists. Thus, the average cost function of generalism now is

$$C_G(q) = C_S - E(q) = C_S - e_{in}q. \tag{A1}$$

Next, we introduce external economies. Then, the cost function of generalist becomes

$$C_G(Q) = C_S - E(Q) = C_S - e_{ex}Q, \tag{A2}$$

where Q denotes aggregate output in the generalist market center, with e_{ex} being the external scale advantages parameter. If we consider both types of scale economies jointly, by combining (A1) and (A2), the average cost function of generalist firms is

$$C_G = C_S - e_{in}q - e_{ex}Q. \tag{A3}$$

TABLE 1

Payoff matrix

	I	*J*
I	$E(I,I)$	$E(I,J)$
J	$E(J,I)$	$E(J,J)$

FIGURE 1

Generalists competing in the center and specialists surviving in the periphery

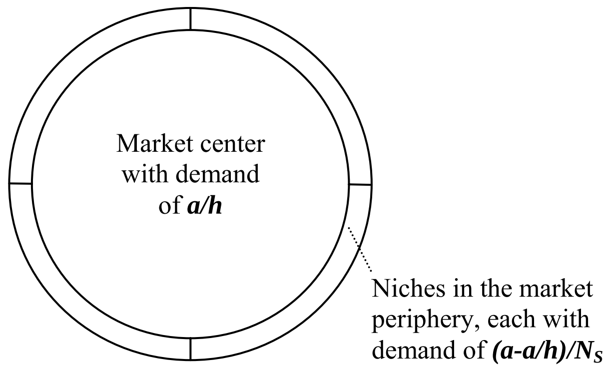


FIGURE 2

The EE of generalists and specialists

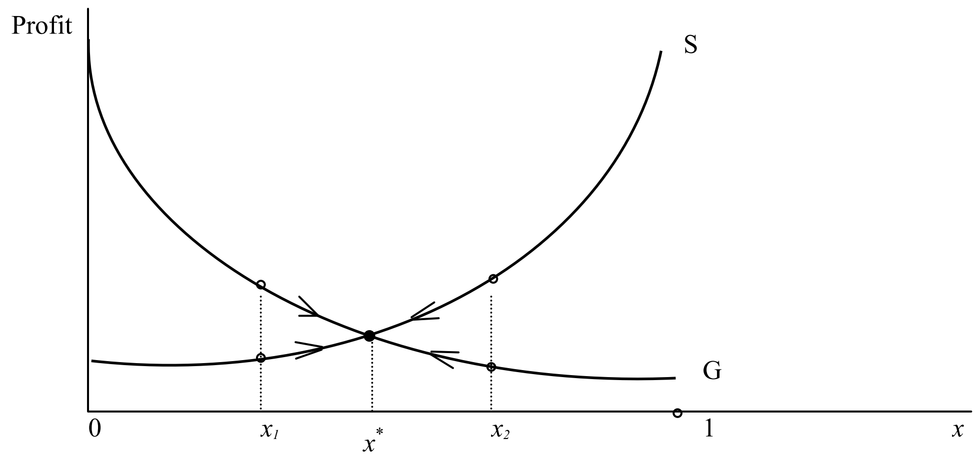
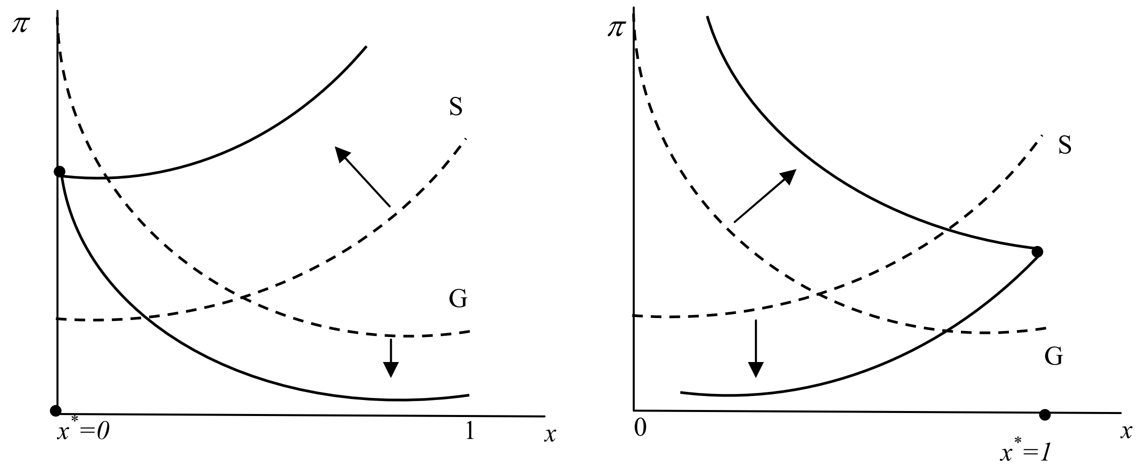


FIGURE 3

The impact of changes in the resource space shape on the EE

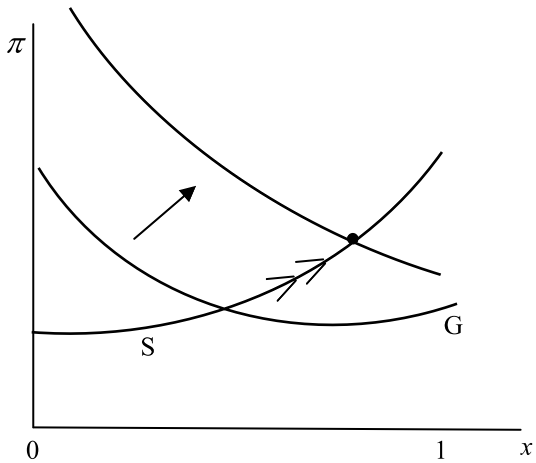


(3a) Value of *h* is increasing toward its maximum

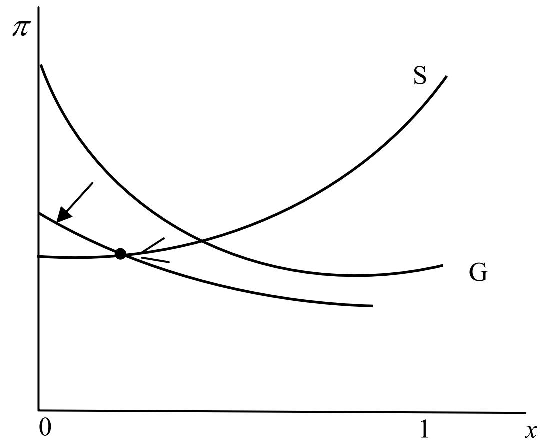
(3b) Value of *h* is decreasing toward its minimum 1

FIGURE 4

The impact of changes in scale economies on the EE



4a) e_{ex} value is increasing



4b) e_{in} value is decreasing

FIGURE 5

Market concentration and competitive release