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Persistence and heterogeneity in entrepreneurship: An evolutionary game theoretic analysis

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ABSTRACT

Studies show that countries exhibit a relatively stable level of entrepreneurial activity. To account for this fact, we adopt an evolutionary game theoretic approach. Based upon the analysis of games that capture essential features of the entrepreneurial phenomenon, we ascertain conditions under which evolutionary stable equilibria will be played by a population consisting of agents who engage in entrepreneurship and agents who do not. We show that entrepreneurship may persist even without assuming strategic complementarities or group selection. Lastly, we explain how information about equilibrium payoffs to self- and paid employment could help address the question of whether entrepreneurs differ from other economic agents.

1. Executive summary

Empirical studies suggest that despite cross-sectional and longitudinal fluctuations, the prevalence of entrepreneurial activity may be a structural characteristic of a country (Minniti et al., 2005; Acs et al., 2004). Furthermore, substantial evidence demonstrates that risky and safe behavior, innovation and imitation, and more specifically, paid and self-employment have coexisted throughout history (Baumol, 1990; Parker, 2004). These facts raise the question of which individual behaviors could lead societies to exhibit a relatively stable proportion of people who start businesses and individuals who do not.

Several frameworks have been developed to address this question. These frameworks usually rely upon at least one of the following three assumptions. The most common among them is the supposition that entrepreneurs differ from other economic agents in terms of their preferences, endowments, personality traits or cognition (Busenitz and Barney, 1997; Casson, 1982; Holmes and Schmitz, 1990; Jovanovic, 1982; Kihlstrom and Laffont, 1979; Lucas, 1978; Knight, 1921; Schumpeter, 1934). Depending on the model, entrepreneurs may be more willing to take risks, more skilled or more confident than other economic agents. Second in prevalence is the assumption that entrepreneurial activities entail positive externalities, a premise motivated by the fact that other economic agents benefit from entrepreneurs when the latter take the risk of exploring unknown paths and exploiting novel opportunities (Bolton and Harris, 1999). Less common but still implicit in many arguments is the presumption that entrepreneurs provide a competitive advantage to the societies in which they interact and that this explains the survival of cognitive biases like overconfidence, which are usually ascribed to entrepreneurs (Bernardo and Welch, 2001).

Undeniably, these assumptions focus on crucial aspects of entrepreneurship. We nevertheless argue that in order to enhance our understanding of the entrepreneurial phenomenon, one must ask whether we need to assume heterogeneous agents (in terms of either their preferences toward risk or their personality traits), positive externalities and/or group selection to justify the fact that entrepreneurship coexists with paid employment. The reason for this is twofold. First, there is no conclusive evidence of the existence of a well defined set of psychological traits distinguishing entrepreneurs from non-entrepreneurs (Brockhaus and Horwitz, 1986; Gartner, 1988; Parker, 2004), and secondly, abundant examples demonstrate that entrepreneurial undertakings

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occur even when they fail to improve the absolute and the relative well being of societies. Current models of entrepreneurship make these assumptions, and we lack a theory that explains why entrepreneurship persists in their absence. To address this issue, we adopt an evolutionary game theoretic perspective, focusing on the competitive aspect of the entrepreneurial phenomenon rather than focusing on its positive externalities and considering individual fitness instead of group selection.

Evolutionary game theory is concerned with the evolution of behaviors whose payoffs are frequency-dependent. Consistent with myopic decision-making at the individual level, evolutionary game theory assumes the relative growth of behaviors that are performing better than average at a particular moment. This is a suitable assumption in modeling entrepreneurship because entrepreneurs usually lack the necessary information to predict the strategies of other economic agents and to optimize their performance accordingly (Busenitz and Barney, 1997). Evolutionary games are suitable for addressing several questions, such as under which conditions long-run aggregate behavior will settle into some equilibrium, and when certain behaviors will become extinct.

The contributions of this article are threefold. First, we show that both self-employment and paid employment will coexist in equilibrium as long as not only the potential gains but also the potential losses of entrepreneurship are high enough. Second, we show that entrepreneurship will persist under more stringent conditions, namely the absence of strategic complementarities and individual, as opposed to group, selection. Third, we demonstrate that it is not necessary to assume entrepreneurial and non-entrepreneurial personality traits to justify the coexistence of paid and self-employment. In our framework, individuals do not even need to earn idiosyncratic payoffs for both occupations to coexist. Of course, economic agents may differ in terms of their abilities. If so, they will choose strategies based on their particular skills and earn idiosyncratic payoffs. On these grounds, the conclusion is that the mere observation of the coexistence of self- and paid employment is not sufficient to demonstrate that economic agents are bound to choose occupations because of idiosyncratic traits or skills. To disentangle this empirical matter, our framework suggests comparing the average earnings of entrepreneurs and non-entrepreneurs. The relevant empirical evidence is mixed, but it suggests that, at least in the US, the earnings differentials are not large. It would therefore be premature to reject the hypothesis that entrepreneurs and other economic agents are homogeneous.

2. Introduction

The aggregate level of entrepreneurial activity varies considerably between countries (Bosma et al., 2008; Bosma and Harding, 2006). However, several studies show that these differences have persisted over the years, suggesting that the rate of entrepreneurial activity may be a structural characteristic of a country (Acs et al., 2004; Minniti et al., 2005). Furthermore, although the time series of aggregate rates of entrepreneurship display significant variations over long periods of history (Parker, 2004), entrepreneurial endeavors have existed since ancient times, at least if they are defined as the undertaking of uncertain projects with the potential for economic gain and social prestige (Baumol, 1990).

At first glance, and acknowledging that entrepreneurial activities are capable of improving not only the relative wealth of those pursuing them but also the productivity of society as a whole, it seems obvious that the processes shaping the evolution of economic and social interactions would select and retain the strategies leading to them. In fact, each year, around 10% of the working population of the countries surveyed by the Global Entrepreneurship Monitor undertakes action towards the initiation of a new business (Reynolds et al., 2001). However, most individuals in the workforce never take steps towards self-employment, and many of those who try fail. Furthermore, not every entrepreneurial undertaking contributes to the welfare of society. Rent-seeking behavior and other unproductive activities may also fall within the scope of entrepreneurship (Baumol, 1990). This raises the main question addressed in this article—namely, under what conditions individual behaviors lead societies to exhibit a relatively stable proportion of people who start businesses in relation to individuals who do not.

This question has been previously addressed with general equilibrium models of occupational choice. These frameworks typically assume a continuum of utility-maximizing agents who differ in terms of their entrepreneurial abilities (Jovanovic, 1982; Lucas, 1978; Holmes and Schmitz, 1990), attitudes towards risk (Kihlstrom and Laffont, 1979) or initial endowment (Banerjee and Newman, 1993). In these models, there is always a marginal entrepreneur who is indifferent towards either self-employment or paid employment and who is found somewhere between the agents for whom entrepreneurship is worth pursuing and those for whom it is not.

These equilibrium approaches, as well as early frameworks in entrepreneurship theory, critically rely upon some kind of heterogeneity in the population of economic agents. Idiosyncratic occupational choices are explained in terms of individual differences in preferences, attitudes, beliefs and/or motivations (Baumol, 1968; Casson, 1982; Kihlstrom and Laffont, 1979; Knight, 1921; Schumpeter, 1934), abilities (Jovanovic, 1982; Lucas, 1978), endowments (Holmes and Schmitz, 1990) and information (Kirzner, 1997). These models have motivated significant strands of empirical research aimed at assessing differences between entrepreneurs and non-entrepreneurs in terms of their personalities, attitudes, or patterns of behaviors. The empirical evidence is inconclusive in this respect. Even though entrepreneurs have not been found to have significantly different personality traits than non-entrepreneurs (Brockhaus and Horwitz, 1986; Gartner, 1988), they have been found to be more optimistic and prone to overconfident behavior (Busenitz and Barney, 1997; Cooper et al., 1988; Fraser and Greene, 2006; Lowe and Ziedonis, 2006; Simon et al., 2000).

Human beings may differ from one another in many respects. They may have intrinsic preferences for occupations, idiosyncratic attitudes toward risk, uniquely evolved personality characteristics and distinctive skills. They may also possess different endowments, experience, information and beliefs. And finally, they may be subject to different sets of constraints at a given point in time. While some aspects of this *generic heterogeneity* may be permanently fixed, others may be context-dependent, and others may in turn self-transform or evolve. In any event, entrepreneurship is an episodic phenomenon ranging from sporadic spells to repeated entry and involving a large and diverse group of people (Bosma et al., 2008; Reynolds et al., 2001). For this reason, theoretical arguments concerning the decision to become an entrepreneur that rely on the existence of a set of stable personal characteristics, which we will term *E-heterogeneity*, are inevitably incomplete (Carroll and Mosakowski, 1987; Shane and Venkataraman, 2000).[1]

A more recent strand of literature focuses on the strategic aspects of the entrepreneurial phenomenon, concentrating on the entrenchment of strategic experimentation and information aggregation in unknown environments (Bernardo and Welch, 2001; Bolton and Harris, 1999). According to these models, entrepreneurial endeavors survive in equilibrium because they mitigate the informational deficiencies of the economic system. Entrepreneurs, innovators and explorers improve the knowledge of those who follow a safe course of action by unveiling information about the potential of untried strategies, novel technologies and uncharted paths. The armed-bandit model of Bolton and Harris (1999) for instance, provides a game theoretical framework for addressing the tension between experimentation and safe behavior. In their model, individuals explore a set of possible actions, learn the stochastic process governing those outcomes and converge to some optimal amount of experimentation. The informational cascades model of Bernardo and Welch (2001) focuses on the selective advantages of overconfidence. In their model, overconfident decision-makers survive in equilibrium by enhancing the relative fitness of the groups in which they interact at small cost to themselves. The dynamic model of geographical agglomeration of entrepreneurial activities and network externalities developed by Minniti (2005) addresses the question of how early high levels of entrepreneurship may become self-reinforcing through a reduction in the ambiguity faced by potential entrepreneurs.

Undoubtedly, this literature focuses on crucial and distinctive aspects of the entrepreneurial phenomenon. Still, we ask whether it is necessary to assume *E*-heterogeneity, strategic complementarities and/or group selection to theoretically justify the fact that entrepreneurship coexists with other occupations. This question is important for three reasons. First, research aimed at identifying a set of distinctive personality traits and thereby characterizing *E*-heterogeneity has led to the conclusion that psychological features of this sort, even when they enhance our understanding of some aspect of entrepreneurial behavior, are neither necessary nor sufficient to explain entrepreneurship (Gartner, 1988; Parker, 2004; Sarasvathy, 2008). Second, entrepreneurial endeavors, although predominantly productive, may also fall into the category of unproductive and sometimes even destructive activities (Baumol, 1990). Third, although it is empirically possible, group selection may be subject to parametric constraints (Henrich, 2004). Therefore, if there are grounds to doubt that the previous assumptions—that are sufficient conditions for entrepreneurship in some models—always hold, then to improve our understanding of the entrepreneurial phenomenon, it is indispensable to ask whether entrepreneurship will survive when they are false.

We address this issue from an evolutionary game theoretic perspective (Friedman, 1991; Maynard Smith, 1982). Evolutionary game theory models the evolution of behaviors characterized by frequency-dependent fitness. In these models, randomly selected individuals play games under the assumption that available strategies or behaviors follow a given rule of replication. The canonical rule of replication is that of the replicator dynamics, which assume that a population playing a particular strategy grows in proportion to how well the strategy has performed in the previous period, relative to the mean population payoff. Evolutionary game theory focuses on a particular subset of Nash equilibria, namely evolutionary stable strategies. These strategies are such that if almost everybody in the population adopts them, they cannot be invaded by small groups adopting different behaviors. In this setup, strategies need not be optimal to spread; they just need to be better than average. To persist in the long run, on the other hand, strategies need to be able to resist the invasion of any other strategy.

We analyze two simple games that capture fundamental features of the entrepreneurial phenomenon: a market-entry game and a game in which individuals decide between a safe and a risky action, as in occupational-choice situations. We consider homogeneous, generically heterogeneous and *E*-heterogeneous populations to assess the effect of personal traits and skills on the propensity to become an entrepreneur. Applying extant results from evolutionary game theory, we determine conditions for the existence of an evolutionary stable equilibrium in which only a fraction of the population engages in entrepreneurship; we then analyze the extent to which this outcome could characterize long-run equilibrium in a population of homogenous individuals. Furthermore, we consider the effect of generic and *E*-heterogeneity upon this dynamics and argue that our framework provides a criterion to use in assessing an empirical question at the core of entrepreneurship theory: namely, whether entrepreneurs differ from other economic agents in terms of idiosyncratic factors that affect the adoption of entrepreneurship. According to our framework, individuals who adopt strategies constrained by factors affecting their payoffs should expect different earnings in equilibrium. We argue that although the empirical evidence is inconclusive, it seems insufficient for us to reject the homogeneity hypothesis. This paper advances the literature not only by enriching the set of theoretical perspectives open to the field (Minniti and Lévesque, 2008) but also by proposing an alternative test that can be employed to answer a core research question.

3. The ecological perspective on entrepreneurship

The ecological approach to the study of the entrepreneurial phenomenon created an important shift in the theoretical focus of the field from the characteristics of the entrepreneur to the environmental conditions affecting organization founding rates (Hannan and Freeman, 1977; Aldrich, 1990). The so-called *rates* approach concentrates on the processes affecting founding rates and stresses the importance of considering groups, organizations, populations and communities as non mutually reducible and therefore complementary levels of analysis (Aldrich, 1979; Aldrich and Martinez, 2001). According to this view, entrepreneurship research involves understanding not only the process through which firms are founded but also the interplay between entrepreneurial strategies like entry, innovation, and imitation at the population level.

[1] We are indebted to Saras Sarasvathy for having suggested the conceptual difference between *generic heterogeneity* and *E-heterogeneity*.

The ecological perspective is based upon the concepts of variation, adaptation, selection and retention (Aldrich and Martinez, 2001). Entrepreneurial undertakings—as long as they entail new organizational structures, products, technology or markets—constitute sources of variation. These undertakings may, at the same time, involve processes of adaptation aimed at adjusting to the environment with the goal of survival. The environmental circumstances and the strategies adopted by others determine, in turn, which behaviors are selected; then, to the extent that these behaviors are replicated, they are retained by the system. Regarding the relative importance of selection and adaptation as drivers of organizational change, Hannan and Freeman (1984) argue that selective mechanisms are justified in environments characterized by uncertainty, instability, and poorly understood connections between means and ends because under these conditions, individual intentions and organizational outcomes are weakly intertwined. Lacking a well structured body of knowledge from which to draw behavioral repertoires and established routines to apply them, entrepreneurship naturally qualifies for the application of evolutionary dynamics (Dosi, 1997).

The contribution of the ecological approach to entrepreneurship was multifaceted. First, by concentrating on the processes leading to the creation of organizations, it shifted the focus from intentions to outcomes and adopted an essentially dynamic approach. Second, by considering both intra- and inter-population processes, it created a focus on the aggregate aspect of the founding phenomenon and its interaction with the environment. Third, by emphasizing the importance of nonlinearities and increasing returns, it acknowledged the path-dependent character of organizational foundings (Hannan and Freeman, 1977; Nelson and Winter, 1982), and fourth, by conceptualizing entrepreneurs as either innovators or reproducers, it drew attention to two important behaviors that species use to act upon their environments. Having highlighted the general relevance of the ecological approach to entrepreneurship, in the next section we explain the motivation for our adoption of evolutionary game theory.

4. Evolutionary game theory and the social sciences

Succinctly defined, evolutionary game theory models evolution at the behavioral or phenotypic level when the relative fitness of particular behaviors depends on their frequency in the population (Maynard Smith, 1982). Evolutionary games are games played by randomly selected individuals in large populations under the assumption that available strategies or behaviors follow a given rule of replication. Evolutionary game theory focuses on evolutionary stable strategies. These strategies are such that if most people in the population are adopting them, they cannot be displaced by small groups of individuals adopting different behaviors. Evolutionary game theory is suitable for addressing several types of questions (Friedman, 1991, 1998; Hirshleifer, 1977). For instance, under which conditions will long-run aggregate behavior settle into equilibrium? When will certain behaviors become extinct? What range of initial conditions would lead to a given pattern of behaviors? What effects will parametrical changes exert upon the dynamics of the system?

This framework deals with myopic decision-makers: individuals who base their choices on the aggregate patterns of the previous period. This is a suitable assumption in modeling entrepreneurship because entrepreneurs usually lack the necessary information to forecast the behavior of competitors, customers and other economic agents (Busenitz and Barney, 1997). Moreover, in complex and uncertain environments, it is difficult to optimize and plan ahead. Individuals often observe which strategies have worked well for other people and adopt them (Friedman, 1991; Nelson and Winter, 1982). Another characteristic of evolutionary game dynamics that naturally suits the entrepreneurial phenomenon is that aggregate behavior exhibits inertia. Uncertainties and adjustment costs lead to slow and gradual changes in the population shares of the strategies. These features and the fact that evolutionary games are played in large populations, where the chance of meeting the same opponents again is small, justify players' myopic behavior (Friedman, 1998). Another reason to set aside issues related to repeated play—like those of trying to predict, influence and adapt to the strategies of specific players—is that we are concerned with initial entry—i.e. decisions made by entrepreneurs before they discover their source of competitive advantage or the strength of their competitors (Camerer and Lovallo, 1999).

The usual mechanism that regulates the replication of behaviors in evolutionary game theory is that of replicator dynamics, which assumes that a population using a particular strategy grows in proportion to the performance of that group in the previous period relative to the mean population payoff. This dynamics is compatible with different assumptions regarding individual behaviors. First, we could think of players as being programmed to use certain strategies and reproduce at rates that depend on their relative payoffs. Second, we could assume that players play only once and are replaced by new ones after leaving the system. The incoming players observe the payoffs of the strategies used in the previous period and choose strategies that yield better-than-average payoffs. Third, we could think of players as sampling from the pool of previous behaviors and adopting randomly sampled behavior. Replicator-like dynamics is also compatible with models of bounded rationality in which players revise strategies as soon as their aspiration levels are not satisfied (Weibull, 1995; Fudenberg and Levine, 1998). The use of this dynamics in cultural systems (as opposed to biological systems) can be justified by empirical evidence showing that successful behaviors are disseminated through imitation, social learning, and other forms of cultural transmission and that these mechanisms operate not only between but also within generations (Nelson and Winter, 1982; Friedman, 1991, 1998; Richerson and Boyd, 2005; Henrich and Boyd, 2008).

Cultural evolution theorists have thoroughly studied the extent to which selection mechanisms provide a useful characterization of cultural transmission processes. Although this topic falls beyond the scope of this article, we would like to point out two important lessons from this field of research (Henrich et al., 2008). First, it is important to take into account the *population-level* consequences of individual behaviors and interactions. In this respect, if genetic factors were found to affect the likelihood of engaging in entrepreneurship as it is conjectured in Nicolaou and Shane (2009), their replication would still

	E	~E
E	π - C , π - C	π , w
~E	w , π	w , w

Fig. 1. Payoff table of the symmetric market-entry game with pairwise interaction.

depend upon the aggregate effects of the biological and cultural fitness of individual behaviors. In other words, both innate and acquired behaviors would be subject to the selection forces shaping social and economic interactions.[2] Second, the fact that cultural transmission is built upon a richer and more complex range of psychological processes than is genetic inheritance, including most notably non-random mechanisms like conformist and prestige-biased transmission of behaviors, does not preclude the role of natural selection as long as there is enough variation in the pool of behaviors.[3]

5. Entrepreneurship from a game theoretic evolutionary perspective

It is impossible to capture the complexity of the entrepreneurial phenomenon with a simple game. Still, the extant literature points to two main stylized representations of entrepreneurship. The first corresponds to the view that entrepreneurship entails *environmental* uncertainty. According to this perspective, the entrepreneur is portrayed as a single decision-maker engaged in either the creation of a new venture or the choice of an occupation. This decision entails environmental uncertainty because it involves payoffs randomly drawn from an unknown distribution. It is said that the payoffs are chosen by *nature* to reflect the fact that these outcomes do not arise out of strategic moves or choices interdependent with those of the entrepreneur. Prototypic examples include the introduction of a new product into the market, decisions concerning the exploration and exploitation of opportunities in natural setups and market-entry strategies in perfectly competitive markets.[4] The second representation of entrepreneurship corresponds to the view of entrepreneurship as involving *strategic* uncertainty. From this perspective, entrepreneurs are modeled as decision-makers whose choices depend on those of other economic agents, like stakeholders, competitors, consumers, venture capitalists, governmental authorities and so on. According to this view, decisions made by other economic agents will affect not only the payoffs of the entrepreneur but also her decisions. For this reason, they cannot be regarded as exogenously given as in the case of environmental uncertainty. Archetypical examples are entry strategies in markets characterized by imperfect competition, decisions involving alternative technologies in the presence of externalities and strategies for the acquisition of financial resources under asymmetric information.

With these perspectives in mind, we model entrepreneurs as playing two games. The first one is a market-entry game that captures the strategic uncertainty faced by entrepreneurs who enter a market that already exists (Rapoport et al., 1998).[5] In this type of interaction, entrepreneurial success depends not only on the entry decision of the individual but also on the entry decisions of the other players because it is assumed that the market has a fixed capacity. The second game is akin to occupational choice under uncertainty because entrepreneurial success does not depend on what potential entrants or competitors do. Entrepreneurs may earn positive and negative profits; however, these outcomes are governed by unmodeled factors such as technology, consumer demand and macroeconomic variables, all subsumed under the heading of *nature*. The strategic aspect of this game is that the payoff of paid employment depends on whether the other player chooses entrepreneurship: an employee earns higher wages if she interacts with an entrepreneur than if she interacts with another employee. This game aims to characterize, albeit abstractly, the introduction of new products and, more broadly, engagement with environmentally uncertain prospects. Whereas in the first game, entrepreneurship is limited by the capacity of the market, in the second, it is bounded by a more complex array of elements that need not pit one entrepreneur against another. In the next subsections, we present these games and analyze the stability of their equilibria.

5.1. A symmetric market-entry game from an evolutionary perspective

Consider a large population of individuals who decide every period simultaneously and without communication between one another to enter into a given market (E) or not to enter ($\sim E$). We start by assuming that individuals play this game pairwise after being randomly chosen. The payoff matrix is displayed in Fig. 1. If only one player enters, the payoffs are π to the entrant and w to the player who stays out. If both players enter the market, competition drives individual profits down by an amount equal to C. No entrance ($\sim E$) yields a safe payoff equal to w. We assume that market entry entails a worse payoff than a safe job when both players enter and a higher payoff when nobody else enters the market—namely, $\pi - C < w$ and $\pi > w$. Note that the risk involved in

[2] To encompass the effect of genetic factors on entrepreneurship, our model would have to be expanded to consider the interaction between sexual reproduction and cultural transmission because the evolution of behaviors that are genetically determined takes place in the gene pool. As it stands, our paper models cultural transmission.

[3] Nicolaou and Shane (2009) show how complex the paths from genetic inheritance to entrepreneurship can be. Yet, the transmission paths of cultural inheritance systems are even more complex. For example, the set of cultural parents is not only larger and endogenously determined but is also variable compared to the set of biological parents, which is given, unambiguous and definitive (Boyd and Richerson, 1985).

[4] A framework to deal with this type of decision and examples can be found in Choi et al. (2008).

[5] This game has a similar structure than the one introduced by Arthur (Arthur 1994a).

this decision is strategic because it depends on the choices of other potential entrants. For instance, the best response of an individual who expects the other to enter is to stay out and choose paid employment. In this game, the actions of the individuals are *strategic substitutes* (Bullow et al., 1985) because the coincident choice of entrepreneurship lowers the payoffs of both players. Individuals will be better off if they can choose non-coincident strategies: in that case, those who enter the market will meet others who stay out and obtain higher payoffs on average.

We could assume that C and π are random variables with either an unknown or a known distribution. However, this uncertainty would not add any substantial insight to the question under analysis, which is how players coordinate or allocate themselves between the two activities. Furthermore, in evolutionary games, players need not know their payoffs at all. Players may take action after thoughtful consideration, but behavior may also be guided by rules of thumb, social norms or analogies with similar situations (Samuelson, 1997). Evolutionary game theory dispenses with individual rationality and focuses on population dynamics driven by selection mechanisms.

We begin our analysis by asking the following question: is there any strategy in this game such that if most members of the population adopt it, then no other strategy can displace it? To answer this question, we need to define the concept of evolutionary stable strategies and then check for which strategies it is satisfied. A strategy is evolutionary stable if and only if (i) it yields a greater or equal payoff *against itself* than does any other invading strategy and (ii) if it yields the same payoff as any other invader against itself, then it yields a greater payoff than any invader *against the invader* (Maynard Smith, 1982). The first condition guarantees the existence of an equilibrium: once the population has reached the evolutionary stable state, no single individual can profit from unilateral changes in behavior. The second condition concerns the stability of this state. It assures that the population will return to it if slightly perturbed.

In our game, each strategy is the best reply against the other but not against itself. Therefore, neither E nor $\sim E$ can be evolutionary stable and overtake the entire population (Hofbauer and Sigmund, 1998; Weibull, 1995). To see why, imagine that everybody is choosing entrepreneurship and earning $\pi - C$. Then if, by mistake or experimentation, somebody chooses a safe job, the strategy will enjoy higher fitness (w) and will therefore begin spreading throughout the population (e.g., other individuals will start imitating it). If, on the other hand, almost nobody is an entrepreneur, then *mutants* adopting this behavior will also spread because they will be earning π, which is higher than w. How will the population evolve?

In the present model, the population will evolve to reach a stable state of coexistence where entry will occur with frequency $p^* = (\pi - w)/C$ and no entry will occur with frequency $1 - p^*$ (see Weibull, 1995, chapters 2 and 3). As one would expect, the probability of entry increases with the expected profit in the absence of competition (π) and decreases with the opportunity cost of entry (w) and the expected losses because of competition (C). In this stable state, the probability of being paired with an entrant is p^*, so that the expected payoff of entry, $p^*(\pi - C) + (1 - p^*)\pi$, equals the payoff of the safe choice w. To check for stability, imagine that a small pocket of individuals enters with a probability $q > p^*$. Call these types q- and p^*-entrants, respectively. Condition (i) holds with equality because any strategy yields w against p^*. Therefore, we have to verify condition (ii). Assume that in the population, market entry occurs with frequency q. The expected payoff accruing to q-entrants is $F(q,q) = q[q(\pi - C) + (1 - q)\pi] + (1 - q)[qw + (1 - q)w]$, whereas the expected payoff accruing to p^*-entrants is $F(p^*,q) = p^*[q(\pi - C) + (1 - q)\pi] + (1 - p^*)[qw + (1 - q)w]$. Comparing these equations, we may easily verify that the second condition holds if $C > 0$. An important lesson from this simple model is that in games or market interactions in which the cost of competition is high relative to the rewards of success, we expect to find pluralistic behavior.

In the previous analysis, we assumed pairwise interactions. We can extend this game by considering a setting in which individuals interact with the whole population and the market capacity allows for more than two entrants. In this case, individuals are said to *play the field*. The previous explanation for why the existence of multiple behaviors at the population level is evolutionary stable remains valid here as well. In the definition of evolutionary stable states, we only have to account for the fact that payoffs directly depend on the aggregate frequency of behaviors (Hofbauer and Sigmund, 1998, Chapter 6; Maynard Smith, 1982).

5.2. Individual behaviors

The evolutionary stable state in which E and $\sim E$ coexist can be achieved in two ways. Either every individual enters the market with probability p^* or there are two groups, one committed to E and the other to $\sim E$, containing proportions p^* and $1 - p^*$, respectively, of the population. In other words, if 10% of the population chooses E, either each individual has a 10% probability of adopting the risky strategy or 10% of the population is bound to enter, whereas 90% is bound to stay out.

In the first case, individuals are thought of as randomly choosing between strategies—although, in accordance with a more elaborate justification, individuals are thereby avoiding being outguessed by others. Sigmund (1993) points out that nature abounds with examples of this kind of behavior and observes that active randomization is not actually necessary. Complex deterministic causation may observationally reduce to sheer randomness, and seemingly random decisions may be deterministically triggered by environmental cues and fortuitous events beyond the control of the individual.

In the second case, individuals are thought of as committed to one of the alternatives, and the population is conceived of as consisting of entrepreneurial and non-entrepreneurial types.[6] What sustains the equilibrium is the fact that there is a 10% chance of one's being paired with an individual who enters the market. Note that individuals in a polymorphic stable state have no particular reason to choose either occupation because both yield the same expected payoff. The motives and the sources of the constraints that cause individuals to choose either occupation are left out of the model. Nevertheless, a population containing

[6] Polymorphic populations are not constrained to these extreme types. There could be several types with their own propensity to enter (Sigmund, 1993). An individual's being wedded to a strategy can be seen as a limiting case of randomization because behavior is adopted with probability of either 1 or 0.

these two types will reach the same stable equilibrium as a population containing individuals who may eventually choose entrepreneurship or paid employment.

The important difference is that in the first case, individuals are homogenous, whereas in the second, they are *E-heterogeneous*. Note that the heterogeneity of this stable polymorphism is unrelated to the payoffs. Furthermore, because homogeneous individuals and *E*-heterogeneous types earn the same expected payoff on average, this model cannot distinguish among them on this basis. It will take empirical data to solve this problem (Maynard Smith, 1982). However, this game clearly illustrates that a population of homogenous individuals is capable of displaying pluralistic behavior.

5.3. Role asymmetries

In Section 5.1, we analyzed games in which the individuals did not differ in any way discernible to themselves. This characterization is not always warranted. There are two main sources of asymmetry in a game. First, individuals who are otherwise identical may play different roles; for example, one player may be an entrant and the other an incumbent, or one individual may possess a patent and the other not (Friedman, 1991, 1998). Second, the same combination of strategies may yield different payoffs depending on who uses it. For instance, entrepreneurs may possess different knowledge, different resources and, therefore, different probabilities of success. This section deals with the first case and the next one with the second.

Consider again the game in Fig. 1, in which individuals enjoy symmetric payoffs. Note that players could earn on average more than w if they coordinated their actions using the following conditional strategy: "enter if row player; stay out if column player." With such a strategy, individuals would earn π as row players and w as column players. Because their payoffs would be on average higher than w (regardless of the likelihood of one's being in a particular role), this behavior would clearly satisfy the conditions for evolutionary stability. In an evolutionary setting, individuals using such a strategy would spread out by avoiding the costs of competition (C) and eventually displace any alternative behavior—including the pluralistic or polymorphic evolutionary stable state analyzed in Section 5.1 (Selten, 1980). The initial conditions will determine whether the row or the column player chooses entrepreneurship. In any case, in the evolutionary stable state, individuals will enter the market in one role only. Individuals do not need to alternate roles for this equilibrium to hold if they belong to separated populations and if interactions pit one population against the other. In equilibrium, individuals in one population enter the market while individuals in the other stay out. Populations specialize, thereby earning different payoffs. If, on the other hand, interactions occur within one population, the conditional strategy referred to above is played by everyone yielding an expected payoff of $(\pi+w)/2$ (assuming both roles are equally likely).

This type of equilibrium loses empirical relevance when the identification of roles is subject to noise (or uncertainty) and when interactions involve many individuals, as we expect to be the case in most entrepreneurial contexts. Roles are more likely to arise in dyadic encounters than when the payoffs of a strategy depend on the aggregate behavior of the population—namely, when individuals play the field (Maynard Smith, 1982; Sigmund, 1993). Furthermore, as one referee points out, roles may be subject to evolution and population membership based on choice: if the other population is earning more, why not move or mutate to improve fitness? If, for instance, the cue that allows correlation relates to human capital or resources (generic heterogeneity), then individuals can in principle switch. If the cue is related to some innate trait (*E*-heterogeneity), then this adjustment is not possible and the cue should be taken as fixed in the short term.[7] In the case of fixed roles, we cannot expect payoff equalization, whereas if roles are subject to choice or evolution, the dynamics of group membership should proceed until the expected payoff equalization.[8]

5.4. Entrepreneurship as an asymmetric game

Market-entry games capture the competitive aspect of the entrepreneurial phenomenon. They assume that the relevant market already exists and that uncertainty is only strategic. However, entrepreneurial undertakings are also affected by a plethora of economic agents, not all of them competitors, and other variables typically summarized by the concept of *nature*. When we picture entrepreneurs as those individuals taking the risk of exploring unknown paths through the creation of new commodities or the discovery of new methods of production, we are mostly envisioning entrepreneurship as a game against nature.

We assume as before that each individual can choose one of two strategies, "entrepreneurship" (E) and "paid employment" ($\sim E$). The choice of E leads to a game against nature with two possible outcomes: a gain and a loss, with probabilities P and $1-P$, respectively. The resultant expected return to entrepreneurship is denoted by π. To introduce a strategic element, we assume that the wage earned when the other individual is an entrepreneur, W, is higher than the wage earned when the other individual also chooses paid employment, w. In this section, we suppose that there are two types of individuals whose payoffs are subscripted, with 1 and 2 to represent the existence of idiosyncratic skills. To avoid confusion, the term "type" will denote idiosyncratic payoff, whereas the term "role," as used in the previous section, will refer to the situation in which there is a cue or a label that allows individuals to identify themselves. This game is depicted in Fig. 2.

In this game, the payoffs of entrepreneurship do not depend on the choice of the other individuals; instead, they only depend on the outcome that is randomly selected by nature. The payoff of paid employment, on the other hand, is higher when the

[7] If we consider the co-evolution of the genetic factors behind *E*-heterogeneity and therefore model the impact of behaviors upon reproductive success, then *E*-heterogeneity can evolve until reaching the equalization of payoffs.

[8] Recall that the role is not supposed to be correlated with the payoff of the strategy. In other words, if having more resources means higher expected payoffs from entrepreneurship, then a conditioning strategy like "enter if resources are available; stay out otherwise" is not an example that is pertinent to the game we analyze here. This type of situation is considered in the next section.

	E	~E
E	π_1, π_2	π_1, W_2
~E	W_1, π_2	w_1, w_2

Fig. 2. Payoff table of the asymmetric game.

individual with whom the employee is paired chooses entrepreneurship: namely, $W>w$. The dynamics of this game will depend on the specific values of the parameters. For $w_1<\pi_1<W_1$ and $w_2<\pi_2<W_2$, the game has the same structure as the one analyzed in Section 5.1, and therefore, entrepreneurship and paid employment will coexist. Beyond these parametric conditions, the strategies cease to be strategic substitutes. Depending on the values of the parameters, evolutionary stability ranges from cases in which both types choose entrepreneurship ($\pi_1>W_1$ and $\pi_2>W_2$) to states in which no type chooses it ($w_1>\pi_1$ and $w_2>\pi_2$). Pluralistic behavior may still occur, not as a result of a strategy's being the best response to the other but as a consequence of there being a strategy that yields a higher payoff regardless of the behavior of the other players (Weibull, 1995, chapter 3). For each region outside the range where $w_1<\pi_1<W_1$ and $w_2<\pi_2<W_2$, individuals have dominant strategies and the game has a unique evolutionary stable state in each region (Weibull, 1995, chapter 2). All possible configurations are illustrated in Fig. 3.

When individuals have idiosyncratic payoffs, it is interesting to ask whether the dynamics of the system will necessarily converge to a state in which the types that choose entrepreneurship are the ones who experience comparative advantage as a result: namely, those individuals who earn a higher profit as entrepreneurs and a lower wage as employees. Consider first the game in Fig. 1 and assume that individuals enjoy idiosyncratic payoffs. In Section 5.3, we explained that in the presence of an environmental cue that could be used as a correlating device, contingent strategies such as “enter in role 1; stay out in role 2” are evolutionary stable. Assume that $\pi_1>\pi_2$ and $w_1<w_2$ and that both roles are equally likely. The question is whether the state in which type 2 individuals choose entrepreneurship and type 1 individuals choose paid employment (call this strategy S_2) can be displaced by the state in which they switch occupations (call this strategy S_1).

From the analysis in Section 5.3, it should be clear that this is not possible. To show why, we can start by observing that the incumbent strategy S_2 yields π_2 and w_1, half the time each. An individual who switches to the opposite strategy (S_1) will be at a disadvantage because he will not be coordinated with the individual playing S_2, thereby earning π_1-C and w_2 half the time each. Under these conditions, this strategy will never be able to spread. Thus, unless a large number of individuals switch at the same time, small disturbances cannot upset the incumbent state. The system can evolve to any evolutionary state, and the final equilibrium will depend on the history of interactions and the initial conditions. In this game, the more skilled individuals need not be those choosing entrepreneurship in equilibrium. The same result would apply to the second game if the expected profit of self-employment lay between the two possible wages.

In the game depicted in Fig. 2, there are two sources of inequality: namely, roles (as in Section 5.3) and idiosyncratic payoffs. When individuals condition their strategies upon their roles, occupations earn idiosyncratic returns. If individuals in role 1 become entrepreneurs and individuals in role 2 become employees, the occupations earn π_1 and w_2, respectively. In the state in which these roles are switched, these earnings amount to π_2 and w_1. In both cases, roles and occupations earn idiosyncratic returns.[9]

Consider now the game in Fig. 2 for parameters outside the region where $w_1<\pi_1<W_1$ and $w_2<\pi_2<W_2$. In each of these regions, there is a unique evolutionary stable state, and at least one individual has a dominant strategy. This means that regardless of the initial conditions, the dynamics will converge to the evolutionary stable state. It is clear from Fig. 3 that the expected payoffs to individuals and occupations will differ in these regions. We will return to this issue in the next section.

5.5. Earnings

In this section, we summarize the results for equilibrium payoffs and characterize the scenarios that produce equal and different occupational earnings.

Equal expected payoffs of both self- and paid employment can arise in symmetric games (Fig. 1) played by homogeneous and polymorphic (*E*-heterogeneous) populations in the absence of behavior contingent on roles. Homogeneous players in equilibrium have a propensity p^* to choose self-employment, whereas *E*-heterogeneous individuals are bound to choose one of the strategies. In the first case, evolutionary forces operate upon the propensity to enter, whereas in the second case, they affect the proportions of *E*-types and ~*E*-types. In both cases, self-employed and paid employed expect the same payoff.

Different expected earnings for the two occupations arise when behaviors are conditioned on roles and types. In a game in which payoffs are symmetrical, like the one in Fig. 1, players may manage to condition their play upon an environmental cue, like their role in the game, or upon some intrinsic feature, like a personal trait. This cue is supposed to be *independent* of the payoffs of the game, *fixed* (sometimes constrained by other interactions) and *known* to the players. These cues need not exist, and if they do, they could be subject to evolution, in which case earnings may tend to balance. Furthermore, when individuals play the field instead of being subject to dyadic interactions, roles are less likely to coordinate choices.

[9] When players condition their play upon their roles or types, they are all using the same strategy. From the point of view of the individual—namely, before types are allocated—the game is symmetric (*ex ante*, every individual is subject to a draw from the same pool of roles and types and earns the same expect payoff in equilibrium). Of course, individuals have no access to the world behind this *Darwinian veil of ignorance*, but this is the level at which the forces of selection operate (Skyrms, 1996).

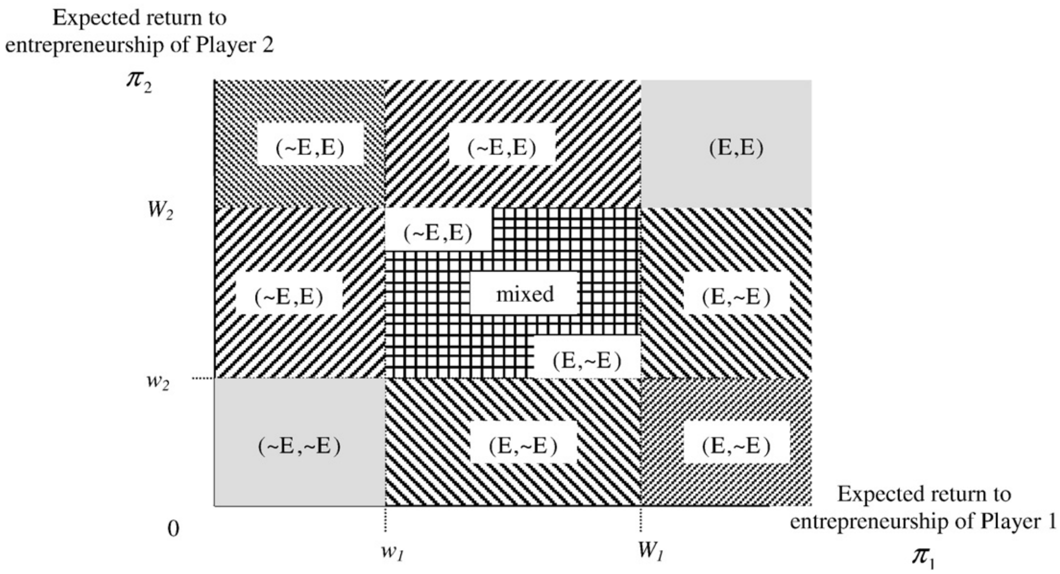

Fig. 3. Possible equilibria in the asymmetric game.

Idiosyncratic payoffs caused by different skills, career paths or particular situational conditions are likely to lead to conditional behavior (Carroll and Mosakowski, 1987; Hofbauer and Sigmund, 1998; Maynard Smith, 1982; Sigmund, 1993). Whereas strategies conditioned on independent *roles* can be seen as a way of earning higher payoffs through coordination, strategies conditioned on *types* or idiosyncratic payoffs may be the result of a constrained optimization of the form "do the best you can, given your type." When individuals choose an action because, due to some intrinsic or history-dependent characteristic, they cannot perform any other, we cannot expect equalization of fitness (Maynard Smith, 1982; Sigmund, 1993). In the asymmetric game shown in Fig. 2, for parameters outside the range in which entrepreneurship and non-entrepreneurship are strategic substitutes (regions with oblique lines in Fig. 3), evolutionary stable states yield *persistent* asymmetric earnings that are the result of idiosyncratic skills. In a nutshell, whereas similar average earnings are compatible with both homogeneous and *E*-heterogeneous (polymorphic) populations, differential average earnings are likely to reflect choices conditioned upon skills if, as discussed in Section 5.3, roles are subject to evolution, or if individuals play the field.

6. Empirical evidence

There are considerable, perhaps insurmountable limits to the application of the previous results to the assessment of field data. First, the properties of the equilibria discussed in this paper are asymptotic. Secondly, our games are at most a coarse approximation of the strategic situations that entrepreneurs and non-entrepreneurs face. Third, real data may fluctuate in the short-run, especially as a result of parametrical changes in the determinants of the relative payoffs of both activities. Ideally, we would need data spanning reasonably long and stable periods of time. With this warning in mind, and considering our criteria as a theoretical benchmark, we proceed to our analysis of the empirical evidence.

Using data from the US Survey of Income and Program Participation covering mid-1983 to mid-1986, Hamilton (2000) investigates earnings differentials in self-employment and paid employment, finding that the median earnings of individuals in small businesses for 10 years are 35% lower than those of employees. Hamilton's results are robust to alternative measures of self-employment earnings, control for self-selection and hold across industries. According to this evidence, only members in the top quartile of the self-employed income distribution earn more through self-employment than through paid employment. Hamilton attributes his findings to non-pecuniary benefits of self-employment, such as flexibility and autonomy. In fact, more than 21% of entrepreneurs surveyed by the *Economic Census Characteristics of Business Owners* in 1992 indicated "being your own boss" as the main reason for entry into entrepreneurship. This empirical evidence is difficult to reconcile with the hypothesis that economic agents are employing pure strategies *conditioned* on idiosyncratic skills.

In the games analyzed in this paper, the payoffs of entrepreneurship are expected returns—i.e., mean incomes. Hamilton analyzed median instead of mean incomes to ameliorate the effect of the large earnings differentials within the self-employed. However, if individuals focus on expected outcomes, then the mean is the relevant measure for analyzing the employment decision. Studies analyzing mean incomes find that male entrepreneurs in the US enjoy greater initial earnings growth on average but that their potential earnings are not significantly different from those of employees (Evans and Leighton, 1989). Other studies in the US further corroborate Hamilton's findings, although they also show that entrepreneurs enjoy substantially greater savings and asset holdings than employees (Parker, 2004). Moskowitz and Vissing-Jorgensen (2002) find that the average returns to private and public market equity in the US are similar despite the first's being considerably riskier. Moreover, this private equity is mostly owned by households that invest in a single privately held company. Unlike data for the US, UK data points to an inverse relationship between earnings through self- and paid employment, although there is disagreement as to the significance of the difference (Parker, 2004). This result is validated by data from the transition economies of Eastern Europe and West Germany (OECD, 1986). Considered as a whole, the evidence on earnings differentials is mixed (OECD, 1986; Parker, 2004) and calls for more research. However, expected earnings differentials seem to be rather small. This evidence calls into question the hypothesis that individuals are employing strategies based on their types. Considering extant evidence against E-heterogeneity, the data on earnings differentials seems to indicate that it may be premature to reject the hypothesis that individuals are homogenous.

7. The evolution of preferences for entrepreneurship[10]

From an ecological perspective, and considering that all mobile organisms need to search their surroundings for resources, it is not surprising that explorative behavior contributes to survival and reproductive fitness in environments characterized by instability, competition and scarcity. Behavioral ecologists have collected abundant evidence on foraging behavior showing that animals are innately prone to exploration and that this behavior consistently varies with situational variables like hunger and predator threat (Krebs and Davies, 1997; Maynard Smith, 1982; Sigmund, 1993). In the domain of the social sciences, on the other hand, we need to address the question regarding the content of human preferences (Berninghaus et al., 2003; Witt, 1991). In this respect, arguments based on the Darwinian theory of organic evolution can at best explain the existence of basic preferences that solved ancestral adaptive problems and enhanced the probability of having surviving offspring (Boyd and Richerson, 1985; Cosmides et al., 1992; Wilson, 1978). Even if explorative behavior is likely to be among those items with a genetic basis, the choice of entrepreneurship in modern economies is far more complex and may not be captured—at least with our current scientific knowledge—at such a basic level.[11] This is where models of co-evolutionary processes involving cultural evolution (Boyd and Richerson, 1985) and innate learning mechanisms in human beings (Witt, 1991) may contribute to explaining the coexistence of genetically and culturally driven behavior. This duality leads to the question of how preferences for certain behaviors can be made compatible with their cultural and biological impact. In this section we attempt to address this question.

In evolutionary games, the payoffs of the players represent their fitness. In biological evolution, the fitness of a behavior is measured in terms of its reproductive success—namely, the expected number of offspring (be they individuals, genes or any other unit of selection). In cultural evolution, the "expected number of offspring" is the amount of individuals who adopt the corresponding behavior in the next period. In other words, the fitness of a behavior represents the extent to which the outcomes of interactions involving that behavior contribute to its replication, either through imitation or via any other mechanism of cultural transmission. For instance, the payoffs of the games analyzed in Section 5 represent the pecuniary income obtained from the corresponding profile of strategies, and we assumed that the higher the income, the larger the chances that the behaviors leading to such outcomes would be adopted in the population.

Empirical evidence shows that entrepreneurship entails non-pecuniary benefits like feelings of independence and a sense of achievement (Hamilton, 2000). Where do these payoffs belong? Are they subject to cultural evolution via imitation? To the extent that individuals can appraise how the non-pecuniary benefits received by others affect their *own* well being, imitation and dissemination may occur via cultural transmission. However, the domain of preferences and well being is not always easily objectivized (Witt, 1991). Therefore, the question remains of whether subjective preferences for entrepreneurship could have evolved.

To answer this question, we apply the so-called "indirect evolutionary approach" developed by Güth and Yaari (1992) and Güth and Kliemt (1998, 2000) to our games.[12] The crux of this approach is the assessment of the evolution of intrinsic preferences for behavior (in our case, preferences for entrepreneurship and paid employment) that in turn determine the fitness of the individuals adopting them. Preferences influence the evolutionary process *indirectly* by motivating individuals to behave in a certain way, and they evolve as the fitness of the behaviors they are disposed to foster determine their prevalence in the population. There is no circularity in this approach because behavioral disposition is assumed to be independent of the fitness or payoffs of the corresponding behaviors.

There is a second reason for undertaking this analysis. In the symmetric game of Fig. 1, individuals obtain on average the same expected payoff both when they are behaviorally homogeneous (they all enter with probability p^*) and when there are types committed to each strategy. Can preferences evolve that break this indifference from the subjective point of view?

Consider the game in Fig. 1 as the one determining fitness and assume that, at the same time, individuals experience intrinsic motivation, either positive or negative, regarding entrepreneurship. These subjective payoffs are displayed in Fig. 4.

In this matrix, parameter m represents a purely subjective motivational factor not based on the objective rewards of the interaction. In principle, m can take any value on the real line. However, we are interested in distinguishing between two types of individuals: namely, those who have a positive, purely subjective disposition towards entrepreneurship and those who experience

[10] We thank one of the reviewers for having suggested this analysis.

[11] Nicolaou and Shane (2009) analyze the many paths through which genetic factors may affect entrepreneurial behavior emphasizing the complexity of such endeavor.

[12] The indirect evolutionary approach is above all concerned with the evolution of altruism and information mechanisms to detect altruistic types. Because in this paper we are concerned with one-shot entry games, it makes sense not to endow players with any information regarding the entry rate of other individuals. In this respect, we are not fully applying this approach.

	E	~E
E	π - C+m , π - C+m	π +m , w
~E	w , π +m	w , w

Fig. 4. Subjective payoffs.

negative motivation. As a first step, "having an intrinsic positive disposition" will be taken to mean that m is such that the individual strictly prefers entrepreneurship to paid employment. Individuals for whom $m > w + C - \pi$ will be called m$^+$-types, and individuals for whom $m < w - \pi$ will be called m$^-$-types. Because in this case individuals have a dominant strategy, they do not need to know the preferences of the others. Decisions are driven by the matrix in Fig. 4, whereas the replication of the rate of entrepreneurship is governed by the payoffs in Fig. 1. Notice that players receive the same income when they choose the same behavior but idiosyncratic subjective rewards. Now we are ready to address the question of whether a population can reach an evolutionary stable state in which m$^+$-types and m$^-$-types coexist. From our previous analysis, it is clear that if m$^+$-types reach a proportion p^* of the population, then this state is stable. A higher proportion of m$^+$-types would increase the rate of entry and the expected payoff of m$^-$-types, driving the proportion of m$^+$-types down.

We consider now a less extreme case in which individuals play E and $\sim E$ with a probability between 0 and 1 (m$^+$-types enter with probability $p^+ > p^*$ and meet m$^-$-types that enter with probability $p^- < p^*$). Evolutionary stability still requires that in the population, entry occurs with probability p^* so that both types have the same expected reproductive fitness. A stable state is reached when the reproductive success of both types is the same (given their entry propensities p^+ and p^-) and when their play is consistent with their preferences as assumed in Fig. 4. This occurs when the proportion of m$^+$-types to m$^-$-types (θ) reaches $\theta^* = [\pi - p^- C - w]/[(p^+ - p^-)C]$, which can be rewritten as $\theta^* = (p^* - p^-)/(p^+ - p^-)$.[13] The application of the indirect evolutionary approach demonstrates that players with idiosyncratic motivations regarding entrepreneurship *can* coexist even when the objective payoffs are independent of their types. In other words, states in which players have symmetrical or homogeneous payoffs but idiosyncratic motivations can be evolutionary stable. The only constraint is that $p^- < p^* < p^+$.

8. Further applications of evolutionary game theory to research in entrepreneurship

Evolutionary game theory is suitable for modeling the interplay between individual behaviors in strategic contexts and its effects at the population level over time. Although originally conceived of to address questions in evolutionary biology, evolutionary game theory has been shown to have valuable applications in the social sciences, spanning from economics (Friedman, 1991, 1998; Güth and Kliemt, 2000; Young, 1998) to anthropology (Boyd and Richerson, 1985; Henrich and Boyd, 2008).[14]

The present paper is a first step towards the application of evolutionary game theory to entrepreneurship. Further research may develop more complex games than the ones analyzed in this paper to deepen our understanding of entrepreneurial undertakings. Future applications of this framework may for instance aim to explain regional differences in the level of entrepreneurial activity, the effects of local interaction upon cluster formation and the evolution of diversified patterns of human capital investment. What kind of contributions can we expect from this framework? As an answer, we briefly outline two research projects.

The literature on entrepreneurial agglomeration is grounded in the notion of positive feedback dynamics arising from strategic complementarities, knowledge spillovers and network externalities, (see Minniti, 2005 for a model of network externalities and further related references). These models assume no inter-regional dynamics and irreversible decisions. Two regions may display idiosyncratic levels of entrepreneurial activity because they evolved out of considerably different initial conditions or because of historical small events that tilted their dynamics toward different equilibrium paths (Arthur, 1994b). Evolutionary game theory could complement this literature by incorporating the migration of individuals and flow of ideas between regions, social learning and flexible or reversible decisions, as is done in Henrich and Boyd (2008). The purpose of such model would be to assess whether entrepreneurial agglomeration still obtains together with its main determinants.

Lazear (2004) shows that under certain parametric conditions, individuals with more balanced skills self-select into entrepreneurship, whereas individuals who excel at only one skill specialize in it. In that framework, the existence of an equilibrium involving entrepreneurship crucially depends on the market value of entrepreneurial talent. If this parameter falls below a certain threshold, no individual opts for entrepreneurship. Using evolutionary game theory, one could model the choice between generalist and specialist strategies (Boyd and Richerson, 1985; Aldrich, 1990) to show that far from being constrained by parametric conditions, generalist strategies are widespread and robust to evolutionary dynamics.

[13] This is just another possible polymorphism supporting the original evolutionary stable state. To encourage the players to enter with probabilities p^+ and p^-, it should be the case that $p^+ = (m^- + \pi - w)/C$ and $p^- = (m^+ + \pi - w)/C$. Note that these equations impose constraints upon m^+ and m^- arising from the condition $0 < p^+, p^- < 1$.

[14] Topics where evolutionary game theory has had seminal applications are altruism, moral behavior, social norms, social learning and signaling systems. See for instance, Skyrms (1996) and Young (1998).

Lastly, research in evolutionary game theory is also suitable for informing research on the influence of genetic factors upon entrepreneurship (Nicolaou and Shane, 2009). First, the genetic make-up of our species *is* already the product of hundreds of millennia of evolution in which the genus *Homo* lived in bands and evolved to solve problems like foraging, mating, parenting, communicating and cooperating (Cosmides et al., 1992; Wilson, 1978). The frequency-dependent nature of such problems is as strategic today as it was in the Paleolithic Age. Hominids that engaged in exploration to find new sources of food were also exposed to failure and to the fate of losing their fitness edge by conferring valuable information. But foraging sources were not mapped and more critically, they were not permanent. Hominids that confined themselves to exploitation most likely disappeared. Thus, what we have termed *strategic uncertainty*, namely the state in which own fitness depends on aggregate behaviors, is as present today as it was during Paleolithic interactions, even when modern survival pressures are not critical (Witt, 1991, 2003). For this reason, game theoretic approaches are able to explain why certain groups of genetic factors could have been favored by natural selection and what behaviors would certainly have become extinct. Second, evolutionary game theory is capable of acknowledging the interplay of cultural and genetic factors and its effect upon the evolution of behaviors.

9. Conclusion

To enrich our understanding of the forces that nurture the coexistence of strategies like entrepreneurship and non-entrepreneurship, as well as their interaction at the population level, we have adopted an evolutionary game theoretic approach. Based on the analysis of two games that capture essential features of the entrepreneurial phenomenon, this paper ascertains conditions under which both self-employment and paid employment will coexist in equilibrium showing that entrepreneurship will be retained in the absence of strategic complementarities and individual selection.

Theories of entrepreneurship often rely upon the assumption that entrepreneurs constitute a *special* species as embodied in the notion of *E*-heterogeneity. We challenge this notion from a theoretical standpoint by demonstrating that it is not *necessary* for the coexistence of entrepreneurship and non-entrepreneurship. Of course, individuals may differ in many meaningful ways. In fact, we expect them to be generically heterogeneous. The crucial question is whether there is a set of stable traits driving the divide between those who become entrepreneurs and those who do not. This paper argues that such a set of traits is not necessary on theoretical grounds. In 2000, Shane and Venkataraman (2000) remarked that existing equilibrium models addressing the question of who becomes an entrepreneur require that people have different attributes. This paper fills a gap by developing an equilibrium model with multiple behaviors and homogeneous agents.

We also show that individuals *may* use strategies conditioned on their abilities and earn, on average, idiosyncratic payoffs. Nevertheless, our conclusion is that the mere coexistence of self- and paid employment is not sufficient to infer either *E*-heterogeneity or idiosyncratic skills. To address this question, our framework suggests examining the average earnings of entrepreneurs and non-entrepreneurs. The relevant empirical evidence is mixed, but it shows that, at least in the US, these differences are not considerable. Therefore, it would be premature to reject the assumption that entrepreneurs and other economic agents are homogeneous in this respect.

The challenge to the notion of *E*-heterogeneity (Carroll and Mosakowski, 1987; Gartner, 1988; Sarasvathy, 2004, 2008; Shane and Venkataraman, 2000) entails important implications for entrepreneurship research, pedagogy, practice and policy. As the quest for the quintessence of entrepreneurial attributes subsides, the diversity of attributes and behaviors *within* the population of entrepreneurs, as well as the plethora of situational variables characterizing entrepreneurial paths, unveil interesting puzzles for investigation (Sarasvathy, 2004). Generic heterogeneity is indeed relevant for entrepreneurship research. Different people will most likely create different ventures and perform idiosyncratically. Understanding these patterns will certainly contribute to the creation of a systematic body of knowledge about entrepreneurship (Sarasvathy, 2004; Shane and Venkataraman, 2000). From an anthropological and methodological perspective, it will be important to investigate the mechanisms behind the dissemination of *entrepreneurship* as behavior. To what extent is this the result of a cultural process, and to what extent is it an outcome of genetically evolved and domain-specific competencies? As for entrepreneurial education and practice, the focus on psychological traits embedded in *E*-heterogeneity has obscured the many ways in which individuals can manage their careers to become entrepreneurs. With the premise that people are not irremediably constrained by their traits, entrepreneurial education will concentrate on providing the skills necessary for the effective creation of ventures and the reduction of avoidable failures. Economic policy aimed at promoting entrepreneurship in general will concentrate on the institutional obstacles hindering potential entrepreneurs once it is acknowledged that these constitute the entire population (Sarasvathy, 2004). These features notwithstanding, the games analyzed in this paper show policy-makers and educators that the room for improvement in rates of entrepreneurial activity and failure is naturally limited by two realities. First, entrepreneurial and non-entrepreneurial activities are strategic substitutes and therefore are incapable of displacing each other. Secondly, in uncertain environments like the ones in which most ventures are created, uncoordinated entry decisions (and therefore, losses) are bound to occur.

From a methodological perspective, the novelty of this paper is that it introduces a framework that has been absent in the entrepreneurship literature. Even when evolutionary game theory abstracts from specific issues of venture creation like the source of opportunities and the process of venture creation, it offers a rich framework for addressing the long-run dynamics of decisions involving strategic risk and is especially suitable for helping us to understand behavior at the aggregate level, an indispensable task when we are assessing the coexistence of multiple behaviors. Evolutionary game theory provides valuable insight into why the rules of the game are conducive to the predicted behavior and exactly how they encourage it. Lastly, this article complements recent works on strategic experimentation and contributes to the interdisciplinary nature of entrepreneurship research by drawing from well entrenched developments in economics, anthropology and behavioral ecology.

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