Entrepreneural Overconfidence and Market Selection*

Jörgen Weibull† and Karen Khachatryan‡

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Abstract

We here study theoretically the possibility that product-market competition among owner-managed firms may select for firms run by overconfident entrepreneurs. We study this possibility in a simple Cournot duopoly for a homogenous good. Each of the two firms is run by an entrepreneur-*cum*-owner who may have incorrect beliefs about his or her firm's production costs. We interpret a tendency to underestimate one's own firm's costs as an expression for overconfidence. We show that market competition selects overconfident entrepreneurs. Indeed, we show that a firm run by an overconfident manager may earn a higher profit than its competitor if the latter firm is run by a manager with correct beliefs about own costs. We also identify and characterize the degree of self-confidence that is evolutionarily rubust and show how this interact with skill and the taste for leisure.

1 Introduction

We here study theoretically the possibility that overconfidence may be an asset in competition, and, more specifically, that firms run by overconfident managers-*cum*-entrepreneurs may earn higher profits than competing firms run by managers-*cum*-entrepreneurs with correct beliefs about their own abilities, as in text-book models. Indeed, market competition may select for a certain degree overconfidence that will prevail in the long run.

We study this possibility in the simplest possible market setting, a Cournot duopoly for a homogenous good. Hence, the two firms' outputs together define the supply in the market

*Preliminary and incomplete.

†Department of Economics, Stockholm School of Economics, Box 6501, SE–113 83 Stockholm, Sweden. E-mail: jorgen.weibull@hhs.se.

‡Department of Economics, Stockholm School of Economics, Box 6501, SE–113 83 Stockholm, Sweden. E-mail: karen.khachatryan@hhs.se.

in question and the market price is determined by equating demand to supply. In our model. each of the two firms is run by an entrepreneur-*cum*-owner who may have incorrect beliefs about his or her firm's production costs. We interpret a tendency to under-estimate one's own firm's costs as an expression for overconfidence. In an extension of this simple model, elaborated in section 6, each firms' production costs are determined by an effort exerted by the entrepreneur-*cum*-owner. In that setting, overconfidence is a tendency to overestimate one's skill as an entrepreneur-*cum*-manager. In this part of our study, each entrepreneur is characterized by three parameters: entrepreneurial skill, taste for leisure and degree of (over- or under-) confidence. Entrepreneurs of the *homo oeconomicus* variety corresponds to the special case of rational expectations. Such individuals know their own skill.

Our main contribution is to formalize these phenomena exactly in a simple and clear model, and to show that market competition indeed selects overconfident entrepreneurs. Indeed, we show that a firm run by a moderately overconfident manager will earn higher profits than its competitor if the latter is run by a manager with correct beliefs about own costs. The intuition is simple: the best response against an overconfident competitor is to cut down one's own production. Since both firms in the duopoly always face the same market price, the firm with the overconfident manager will earn higher profits. However, two competitors run by equally overconfident managers will earn lower profits than two competitors run by managers with correct beliefs. Given this tendency towards moderate overconfidence, and tendency against excessive overconfidence, one may ask what degree of confidence, if any, will prevail in the long run in a given market context, if there is free entry and exit of entrepreneurs with different degrees of self-confidence. In the special case of linear demand in the product market in question, we identify and characterize this degree of self-confidence, which we call the evolutionarily robust degree of self-confidence.

Our study is purely theoretical and speculative. What empirical evidence is there for our hypothesis that those entrepreneurs that prevail in markets are overconfident? Psychological studies show that most people are overconfident about their own relative abilities, see e.g., Weinstein (1980), Weinstein (1982), Weinstein (1984) and Taylor and Brown (1988). When assessing their position in a distribution of peers on almost any positive trait — such as driving ability (Svenson (1981)) or longevity — a vast majority of people say they are above average. Psychologist Shelley E. Taylor sums up much of the evidence on optimistic biases in her comprehensive book on the subject, Taylor (1989), and argues that unrealistic optimism is an indispensable trait of the healthy mind. According to de Bondt and Thaler (1995), "Perhaps the most robust finding in the psychology of judgement is that people are overconfident." Such overconfidence induces individuals to undertake ventures that more balanced-minded individuals might not undertake. For example, overconfidence among entrepreneurs has been documented by Cooper, Woo, and Dunkelberg (1988). In their sample of 2994 entrepreneurs, 81% believe that their chances of success are at least 70% and 33% believe their chances are as much as 100%. In reality, about 75% of new businesses no longer exist after 5 years. Busenitz and Barney (1997) compared entrepreneurs' with managers' knowledge, and confidence in their own knowledge, about a number of real-world issues (e.g., whether cancer or heart disease is the leading cause of death in the United States). Entrepreneurs and managers were found to be approximately equal in knowledge but entrepreneurs' confidence in the accuracy of their own answers was dramatically higher.

Camerer and Lovallo (1999) experimentally studied whether optimistic biases could plausibly and predictably influence entry into competitive games or markets. They found that when subjects' earnings in these games and markets were based on their own abilities, individuals tend to overestimate their chances of relative success and enter more frequently, as compared to games and markets in which earnings do not depend on skill. This overconfidence is even stronger when subjects could self-select into the experimental sessions, well aware that their success would depend partly on their skill and that their competitors had self-selected too. In those sessions, there is so much entry that the average subject lost money in 34 out of 48 periods. This result suggests a new phenomenon specific to competition, which Camerer and Lovallo (1999) call "reference group neglect" — the tendency to under-adjust to changes in the group one competes with.

The consequences of overconfidence in financial markets have been analyzed quite extensively in the behavioral finance literature, see, for example, Kyle and Wang (1997), and Odean (1998). Malmendier and Tate (2005) and Malmendier and Tate (2007) provide field evidence on overconfidence in corporate decisions. They assume that CEOs are likely to overestimate their ability to pick successful projects and to run companies. As such, these top managers are likely to invest in too many projects and overpay for mergers. To test these hypotheses, Malmendier and Tate identify a proxy for overconfidence, and examine the correlation of this proxy with corporate behavior. In particular, they identify as confident CEOs who hold onto their stock options until expiration, despite the fact that most CEOs are heavily under-diversified. They interpret the lack of exercise as overestimation of future performance of their company.

Recent references in the economics literature examining various aspects of overconfidence include Manove and Padilla (1999), Manove (2000), Compte and Postlewaite (2004)and Sandroni and Squintani (2007). A few papers, including Bernardo and Welch (2001) and Heifetz, Shannon, and Spiegel (2007), analyze overconfidence from an evolutionary perspective, in a vein similar to this study.

The empirically established human bias toward overoptimism and overconfidence is most evident in connection with areas of self-declared or self-selected expertise (de Bondt and Thaler (1995)). Thus, the decisions of entrepreneurs are more likely to reflect even more overconfidence than the population at large. Pessimists, who might tend to be excessively conservative as entrepreneurs, would be likely to select other occupations whose outcomes are more predictable and thus less subject to their own pessimistic expectations; that is, they might prefer to be employees rather than entrepreneurs (see the discussion in de Mezza and Southey (1996)).

2 Cournot duopoly

Consider a standard Cournot duopoly for a homogeneous good, with linear demand,

$$P(Q) = 1 - Q$$

where $p = P(Q)$ is the market price when total output is $Q = q_1 + q_2$. Each firm i has a constant unit cost $\tilde{c}_i$, a non-negative random variable with c.d.f. F_i with support in the interval $[0, 1/2]$ and with expectation $c_i = \mathbb{E}[\tilde{c}_i]$. The costs may be correlated.

Each firm is owned and run by an entrepreneur-*cum*-owner. For the sake of brevity, this decision-maker will be called the manager of the firm. The two managers choose their respective firms' outputs simultaneously and do not know the costs at that point in time. Each manager strives to maximize his or her firm's expected profit,

$$\pi_i(q_1, q_2) = (P(Q) - c_i)q_i$$

We solve for Nash equilibrium. Combining the necessary first-order conditions, we obtain

$$q_1^* = \frac{1 + c_2 - 2c_1}{3} \text{ and } q_2^* = \frac{1 + c_1 - 2c_2}{3}$$

These equations define non-negative output levels iff $2c_1 - c_2 \leq 1$ and $2c_2 - c_1 \leq 1$. These latter inequalities are met with probability one, since both random costs lie in the interval $[0, 1/2]$.

Total output and the equilibrium market price are

$$Q^* = \frac{2 - c_1 - c_2}{3} < 1 \quad \text{and} \quad p^* = \frac{1 + c_1 + c_2}{3} > 0$$

respectively. The firms' equilibrium profits are

$$\pi_i^* = \left(\frac{1 + c_{-i} - 2c_i}{3}\right)^2$$

where c_{-i} is the expected unit cost of the other firm.

3 One overconfident manager

Suppose that the both firms' unit cost distributions have the same mean: $c_1 = c_2 = c$. However, the manager of firm 1 believes that his firm's unit cost is drawn from another cost distribution. More precisely, his or her cost expectation is

$$c_1^e = \mathbb{E}\left[\tilde{c}_1\right] / \theta_1 = c/\theta_1$$

for some $\theta_1 > 0$, where θ_1 can be interpreted as the manager's *degree of confidence.* For $\theta_1 < 1$ the manager is *under-confident* while for $\theta_1 > 1$ he is *overconfident.* We will focus on the case of overconfidence: henceforth $\theta_1 \geq 1$. Suppose that this is common knowledge. How does this affect the equilibrium outcome?

The manager of firm 1 solves

$$\max_{q_1} \left(P\left(q_1 + q_2\right) - c/\theta_1\right) q_1$$

and the manager of firm 2 solves

$$\max_{q_2} \left(P\left(q_1 + q_2\right) - c\right) q_2$$

Solving the necessary first-order conditions, we obtain

$$q_1^* = \frac{1 + \left(1 - 2/\theta_1\right) c}{3} \text{ and } q_2^* = \frac{1 + (1/\theta_1 - 2)c}{3}$$

and thus

$$Q^* = \frac{2 - \left(1 + 1/\theta_1\right) c}{3} \text{ and } p^* = \frac{1 + \left(1 + 1/\theta_1\right) c}{3},$$

resulting in profits

$$\pi_1^* = \left(\frac{1 - (2 - 1/\theta_1)c}{3}\right)^2 + \frac{1 - (2 - 1/\theta_1)c}{3}(1 - 1/\theta_1)c$$

$$\pi_2^* = \left(\frac{1-(2-1/\theta_1)c}{3}\right)^2$$

In particular,

$$\pi_1^* - \pi_2^* = \frac{1-(2-1/\theta_1)c}{3}(1-1/\theta_1)c$$

and hence $\pi_1^* \geq \pi_2^*$ for all $\theta_1 \geq 1$, granted $(2c-1)\,\theta_1 < c$, a condition that is met for all $c \leq 1/2$ irrespective of the value of θ_1. The diagram below shows how π_1^* (solid curve) and π_2^* (dashed curve) depend on θ_1 (the horizontal axis), for $c = 0.4$. The thin horizontal line is the profit to each firm when the manager of firm 1 is a standard *homo oeconomicus*; when $\theta_1 = 1$.

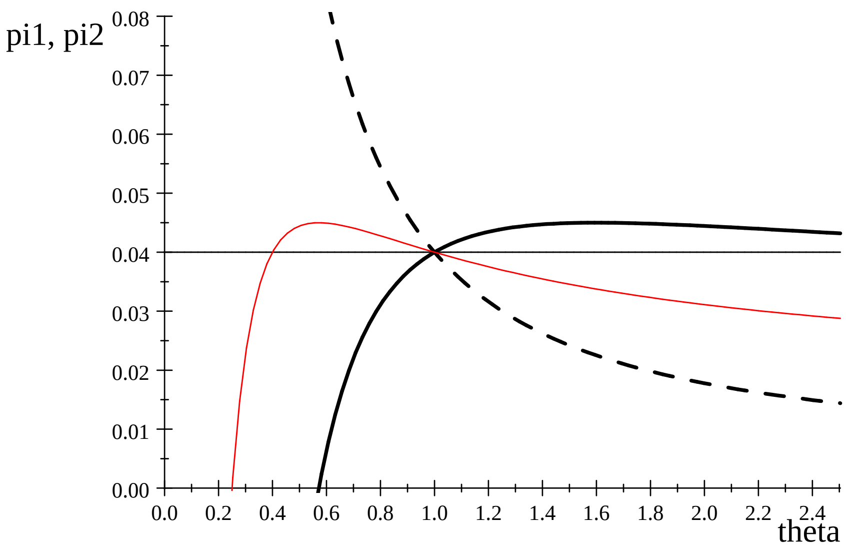

Figure 1

We see in the diagram (i) that an overconfident manager makes a higher profit than *homo oeconomicus*, (ii) that there is an optimal degree of overconfidence, roughly $\theta_1 = 1.6$, (iii) that the overconfident manager makes a higher profit than when two *homo oeconomicus* meet, and (iv) that the industry profit is decreasing in the degree of overconfidence: the thin curve gives the average industry profit across the two firms.

4 Two overconfident managers

Suppose that both firms' unit costs have the same expectation; $c_1 = c_2 = c$. However, now both managers may be overconfident. More precisely, the manager of firm $i = 1, 2$ expects his or her own unit cost to be $c_i^e = \mathbb{E}[\tilde{c}_i]/\theta_i = c/\theta_i$, for some $\theta_i > 0$. Suppose that this is common knowledge. What is now the equilibrium outcome?

Each firm i now solves

$$\max_{q_i} \left(P\left(q_1+q_2\right)-c/\theta_i\right) q_i$$

The necessary first-order conditions imply that

$$q_1^* = \frac{1+c/\theta_2-2c/\theta_1}{3} \quad \text{and} \quad q_2^* = \frac{1+c/\theta_1-2c/\theta_2}{3}$$

and thus

$$p^* = \frac{1+c/\theta_1+c/\theta_2}{3}$$

resulting in profits

$$\pi_i^* = v\left(\theta_i,\theta_j\right) = \left[\frac{1+\left(1/\theta_1+1/\theta_2\right)c}{3}-c\right]\cdot\frac{1+c/\theta_j-2c/\theta_i}{3}$$

for $i=1,2$ and $j \neq i$.

5 Evolutionarily robust self-confidence

We will call a degree of self-confidence θ *evolutionarily robust* if there for every $\theta' \neq \theta$ exists an $\bar{\varepsilon} > 0$ such that for all $\varepsilon \in (0,\bar{\varepsilon})$:

$$(1-\varepsilon)\, v\left(\theta,\theta\right)+\varepsilon v\left(\theta,\theta'\right) > (1-\varepsilon)\, v\left(\theta',\theta\right)+\varepsilon v\left(\theta',\theta'\right) \tag{1}$$

In words: consider a pool of managers who all have the same degree of self-confidence, θ. Suppose that a small population fraction of these would "mutate" to some other degree of self-confidence, θ'. Let $0 < \varepsilon < 1$ be the population share of such "mutants." The expected profit that a manager of the "incumbent" type θ would make when matched against another manager of the same incumbent type would be $v\left(\theta,\theta\right)$, while the expected profit to the same manager if matched against a manager of the "mutant" type θ' would be $v\left(\theta,\theta'\right)$. Hence, the left-hand side in (1) is the expected profit to a manager of the incumbent type when randomly matched against another manager in the pool of managers. Likewise, the right-hand side of (1) is the expected profit to a manager of the mutant type when randomly matched against another manager in the pool.[1] The incumbent degree of self-confidence is thus defined as evolutionarily robust if there exists no other degree of self-confidence that, if appearing in a sufficiently small share of the manager pool, would earn at least the same expected profit as the managers of the incumbent type do, in the mixed population.

[1] We assume that the pool is so large that we do not have to adjust the matching probabilities by first subtracting the manager himself from the pool, before randomizing.

For a degree of self-confidence θ to be evolutionarily robust in this sense, it is clearly necessary that

$$v(\theta,\theta) \geq v(\theta',\theta) \qquad \forall\theta'.$$

In other words, θ should be optimal against itself.[2] Conversely, suppose that θ is optimal against itself. If, moreover, no other θ' is also optimal against θ, then it follows that θ is evolutionarily robust. Hence, it is of interest to find those θ that are optimal against themselves.

It is easily verified, that for any θ, there is a unique θ' that maximizes

$$v(\theta',\theta) = \left[\frac{1+(1/\theta'+1/\theta)\,c}{3} - c\right] \cdot \frac{1+c/\theta-2c/\theta'}{3}$$

namely

$$\theta' = \frac{4c\theta}{6c\theta - c - \theta}$$

The unique fixed-point to this equation is $\theta = \theta^*(c)$, where

$$\theta^*(c) = \frac{5c}{6c-1}$$

This degree of self-confidence is negative if $c < 1/6$ but it exceeds 1 for all $c > 1/6$. We have established:

Proposition 1 *Suppose that* $1/6 < c < 1/2$. *There exists a unique degree of self-confidence that is evolutionarily robust, namely* $\theta = 5c/(6c-1)$.

A few things are worth noting. First, that the evolutionarily robust degree of self-confidence is decreasing in the unit cost, see Figure 2 below.

[2] For if there would exist a manager type θ' that would earn more against θ than θ does, that is, $v(\theta',\theta) > v(\theta,\theta)$, then, for $\varepsilon > 0$ sufficiently small, (1) would be violated.

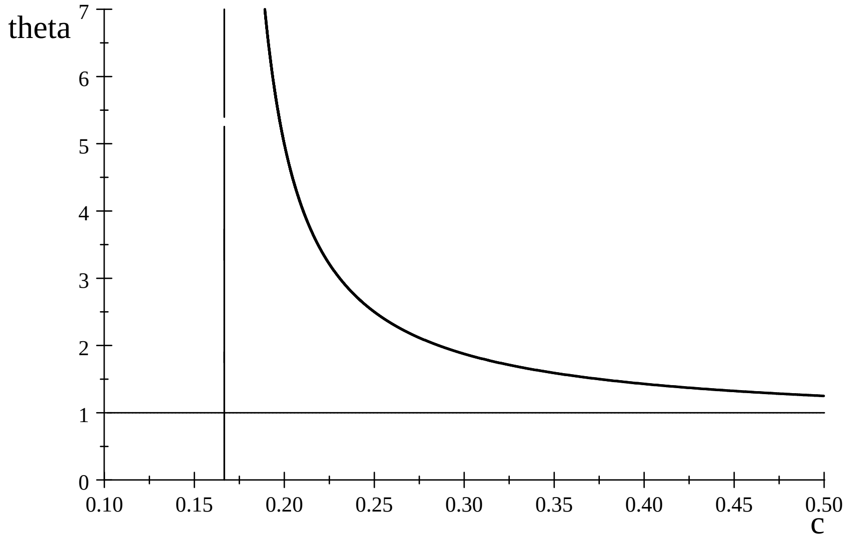

Figure 2

The thin vertical line represents $c = 1/6$, the lower bound on the unit cost for the above calculations to be valid.

Secondly, any manager with the evolutionarily robust degree of overconfidence expects his or her own unit cost to be

$$c^e = \frac{c}{\theta^*(c)} = \frac{6}{5}c - \frac{1}{5}$$

We note that $c^e < c$ and that c^e is increasing in c, from $c^e = 0$ when $c = 1/6$ to $c^e = 0.4$ when $c = 1/2$.

Thirdly, the equilibrium expected profit to each firm, when both firms are run by managers with the evolutionarily robust degree of self-confidence, is

$$\hat{\pi}(c) = v(\theta^*(c), \theta^*(c)) = \left(\frac{1+2c^e}{3} - c\right) \cdot \frac{1-c^e}{3} = \frac{2}{25}(1-c)^2 .$$

The graph of this profit function is shown in Figure 3 below (the thicker curve) alongside the profit function to each firm had they instead been run by *homo oeconomicus*. We note that the equilibrium profit to the overconfident managers is lower. In this sense, the market selects manager types that earn lower profits than *homo oeconomicus* would have done.

Fourthly, and finally, we note that overconfidence among managers is good for consumers. More precisely, as seen in Figure 4 below, the market price is lower when managers are of the evolutionarily robust type (thick curve) than when they are *homo oeconomicus* (thin curve).

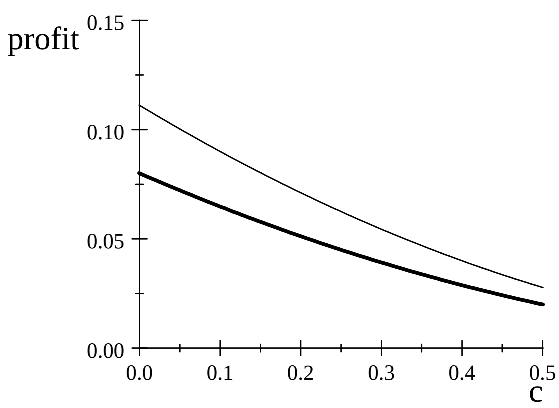

Figure 3

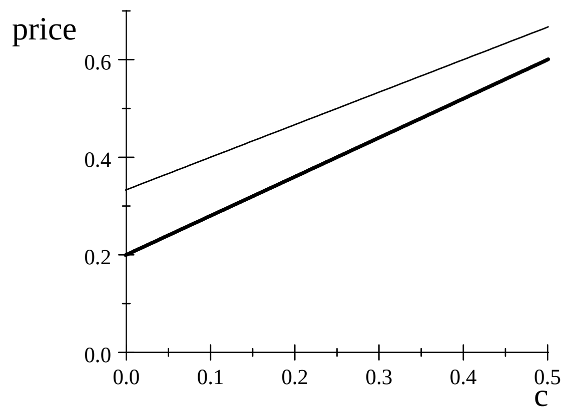

Figure 4

6 Endogenous production costs

In our base-line model outlined above, the unit cost of production is exogenous to each firm. However, in practice, part of an entrepreneur's or manager's task is to find efficient ways to produce the desired output. Weibull (2000) develops a model in which managers-*cum*-entrepreneurs decide how much effort to spend in order to increase their own firm's profit. We here use the parametric example in section 4 of that paper.

Suppose, thus, that each entrepreneur i can influence the probability distribution of his or her own firm's unit cost by way of making some effort. More specifically, let $0 \leq x_i < 1$ be the cost-reducing *effort* made by entrepreneur i, and assume that entrepreneurs have Cobb-Douglas preferences over profit π_i and leisure, defined as $z_i = 1 - x_i$:

$$u_i = (\pi_i)^{\gamma_i} \cdot (1 - x_i)^{\lambda_i}$$

for some $\gamma_i, \lambda_i > 0$.[3] While effort, and hence leisure is decided single-handedly by the entrepreneur, the resulting profit is a random variable that depends on the realization of the random unit cost. We here focus on the case of risk neutral entrepreneur, that is, the special case when $\gamma_i = 1$ and when the (true) mathematical expectation of the unit cost is linearly decreasing in effort,

$$c_i = \mathbb{E}[\tilde{c}_i] = 1 - \sigma_i x_i$$

for some $\sigma_i > 0$, interpreted as the i's entrepreneurial *skill*; if a less skilful and a more skilful entrepreneur would make the same effort, the more skilful will, on average, end up with a

[3]We focus on this class of utility functions because of their analytical tractability. We plan to also investigate linear-quadratic utility functions as well as von Neumann-Morgenstern utilities of the Cobb-Douglas form.

lower unit cost. Allowing for the possibility that entrepreneurs may have incorrect (typically optimistic) expectations about their own skill, entrepreneur i thus strives to maximize his or her (subjective) expected utility,

$$\mathbb{E}_i \left[(1 - q_1 - q_2 - \tilde{c}_i) \, q_i \, (1 - x_i)^{\lambda_i} \right].$$

6.1 Entrepreneurs with rational expectations

Consider two entrepreneurs, $i = 1, 2$, who compete in a duopoly product market, as analyzed above. However, now their unit costs are not fixed and given, but determined by their efforts. They choose their efforts and output levels simultaneously, before unit costs are realized. They have correct expectations about their own costs, $c_i^e = \mathbb{E}[\tilde{c}_i] = 1 - \sigma_i x_i$. Each entrepreneur i then faces a decision problem that can be written as

$$\max_{q_i, x_i > 0} \left[\ln(\sigma_i x_i - q_1 - q_2) + \ln q_i + \lambda_i \ln(1 - x_i) \right]$$

The first-order conditions for entrepreneur i give

$$q_i = \frac{\sigma_i x_i - q_j}{2} \quad \text{and} \quad x_i = 1 - \frac{\lambda_i q_i}{\sigma_i}$$

Combining these, we obtain

$$q_i = \frac{\sigma_i - q_j}{2 + \lambda_i}$$

for $i = 1, 2$ and $j \neq i$. Hence, each entrepreneur responds to the opponent's expected output level with a higher own output, the more skilful the entrepreneur is and the less preference he or she has for leisure. In Nash equilibrium:

$$q_i^* = \frac{\sigma_i (2 + \lambda_j) - \sigma_j}{(2 + \lambda_1)(2 + \lambda_2) - 1}$$

We note that output is increasing in own skill and decreasing in own taste for leisure. The accompanying efforts are, by contrast, decreasing in own skill:

$$x_i^* = 1 - \frac{(2 + \lambda_j) - \sigma_j / \sigma_i}{(2 + \lambda_1)(2 + \lambda_2) - 1} \lambda_i$$

The expected unit cost becomes

$$c_i^* = 1 - \sigma_i + \lambda_i q_i^*$$

and profits are thus given by

$$\pi_i^* = \left(\frac{\sigma_i(2+\lambda_j) - \sigma_j}{2\left(\lambda_1+\lambda_2\right)+\lambda_1\lambda_2+3} \right)^2$$

In the special case of two identical entrepreneurs we obtain

$$\pi_i^* = \left(\frac{\sigma}{\lambda+3} \right)^2$$

an increasing function of σ and decreasing function of λ.

Another special case is when $\lambda_1 = \lambda_2 = \lambda$ and $\sigma_2 = 1$. We then obtain

$$\pi_1^* = \left(\frac{\sigma_1\left(2+\lambda\right) - 1}{\lambda^2+4\lambda+3} \right)^2$$

and

$$\pi_2^* = \left(\frac{2+\lambda-\sigma_1}{\lambda^2+4\lambda+3} \right)^2$$

We note that $\pi_1^* \geq \pi_2^*$ if and only if $\sigma_1 \geq 1 = \sigma_2$.

6.2 Overconfident entrepreneurs

Suppose that the entrepreneurs may be overconfident in the sense of believing that their own skill is greater than it actually is. In order to analyze this question, suppose that entrepreneurs 1 and 2 differ only in their degree of confidence: $\lambda_1 = \lambda_2 = \lambda$ and $\sigma_1 = \sigma_2 = 1$ and $c_i^e = 1 - \theta_i \sigma_i x_i$ for some $\theta_i > 0$. From the above we obtain

$$q_i^* = \frac{\left(2+\lambda\right)\theta_i - \theta_j}{\lambda^2+4\lambda+3} \quad \text{and} \quad c_i^* = \frac{\lambda}{\theta_i} q_i^*$$

and

$$\pi_i^* = \frac{\left(2+\lambda\right)\theta_i - \theta_j}{\left(\lambda^2+4\lambda+3\right)^2} \cdot \left[3+2\lambda-\left(1+\lambda\right)\left(\theta_i+\theta_j\right)+\lambda\theta_j/\theta_i\right]$$

In the special case of two identical entrepreneurs we obtain

$$\pi_i^* = \frac{\theta\left(3-2\theta\right)}{\left(\lambda+3\right)^2}$$

Hence, the common degree of confidence that results in highest profits is $\hat{\theta} = 3/4$, with profits increasing (decreasing) for lower (higher) degrees of confidence.

In the special when entrepreneur 2 has rational expectations, $\theta_2 = 1$, we obtain

$$\pi_1^* = \frac{(2+\lambda)\,\theta_1 - 1}{\left(\lambda^2 + 4\lambda + 3\right)^2} \cdot \left(2 + \lambda - (1+\lambda)\,\theta_1 + \lambda/\theta_1\right)$$

and

$$\pi_2^* = \left(\frac{2 + \lambda - \theta_1}{\lambda^2 + 4\lambda + 3}\right)^2$$

We note that $\pi_1^* = \pi_2^*$ when $\theta_1 = 1$, as it should be. We also note that $\pi_1^* \geq \pi_2^*$ if and only if

$$(2\theta_1 + \lambda\theta_1 - 1) \cdot \left(2 + \lambda - (1+\lambda)\,\theta_1 + \lambda/\theta_1\right) \geq (2 + \lambda - \theta_1)^2$$

The diagram below shows the range of parameter pairs (θ_1, λ) that meet this inequality; this is the area within the thicker curve. We see that firm 1 makes a higher expected profit than firm 2 only if $\theta_1 > 1$ and that this also requires λ to be not too high.

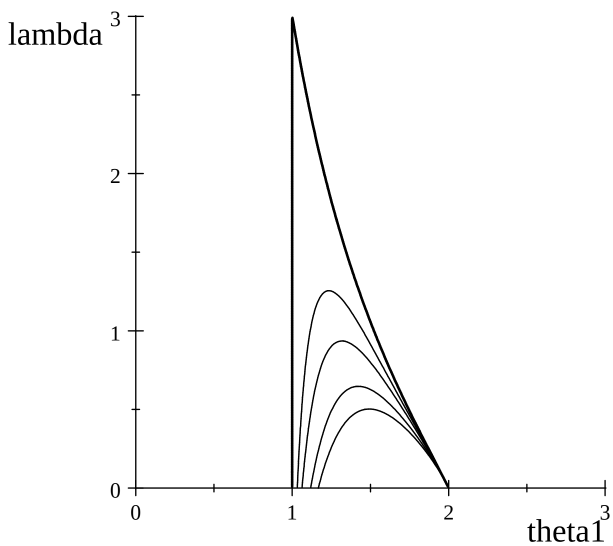

Figure 5

The diagram below plots π_1^* and π_2^* as functions of θ_1, for $\lambda_1 = \lambda_2 = 0.5$. The solid curve is the profit to firm 1, the dashed to firm 2, and the thin horizontal line the common profit when $\theta_1 = 1$. We see that the profit to the firm run by the entrepreneur with rational expectations, firm 2, is decreasing in the degree of confidence of the entrepreneur running firm 1. The thin (red) curve is the average industry profit. We also note that firm 1 earns a higher profit than firm 2 for degrees of confidence between 1 and approximately 1.75.

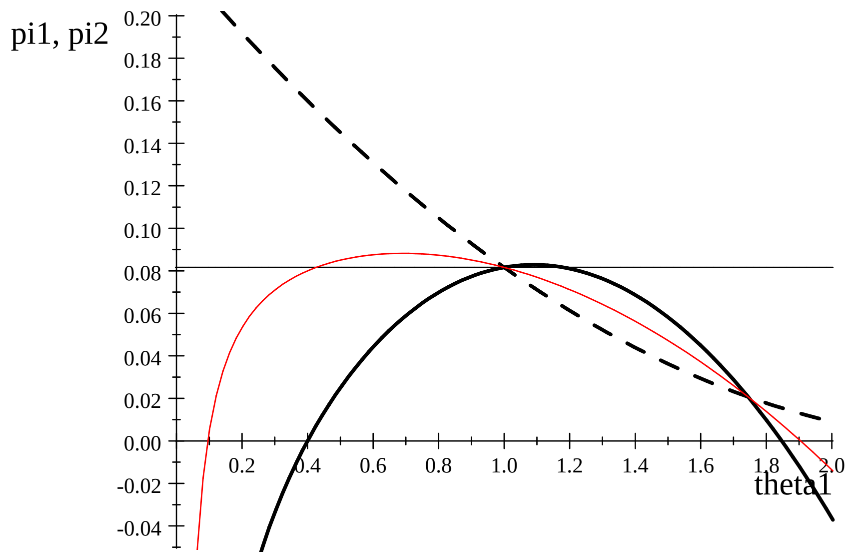

Figure 6

6.3 Evolutionary robustness

We use the approach developed in section 5 and focus on two entrepreneurs with identical tastes and skills, but with potentially differing degrees of self-confidence. Consider, thus, an entrepreneur with confidence θ' who is matched against an entrepreneur with confidence θ. The expected profit to the first can be written as

$$\begin{aligned}\pi^* &= v(\theta',\theta) = \left(1 - \frac{2+\lambda-\theta/\theta'}{(2+\lambda)^2-1}\lambda - \frac{\theta'+\theta}{3+\lambda}\right)\left(\frac{\theta'(2+\lambda)-\theta}{(2+\lambda)^2-1}\right)\sigma^2 \\ &= ((2+\lambda)\theta'-\theta)(3+2\lambda-(1+\lambda)(\theta'+\theta)+\lambda\theta/\theta')\left(\frac{\sigma}{\lambda^2+4\lambda+3}\right)^2\end{aligned}$$

We now look for such a degree of self-confidence θ that

$$v(\theta',\theta) \le v(\theta,\theta) \qquad \forall\theta', \tag{2}$$

with strict inequality for all $\theta' \neq \theta$. We note that this condition for evolutionary robustness is independent of σ : the only parameter that matters when determining whether or not the condition is met by a particular θ is λ.

See Figure 7, plotting the contour map of $v(\theta',\theta)$, with θ' on the horizontal axis and θ on the vertical, for $\lambda = 0.5$ (and $\sigma = 1$). A degree of confidence θ^* meets condition (2) if the tangent of the isoquant through the point (θ^*,θ^*) is horizontal and no other point on the horizontal line through that point has a higher v value. Inspecting the graph it appears to exist a unique evolutionarily robust degree of confidence, approximately $\theta = 1.07$ (this is indicated by the thin vertical and horizontal lines).

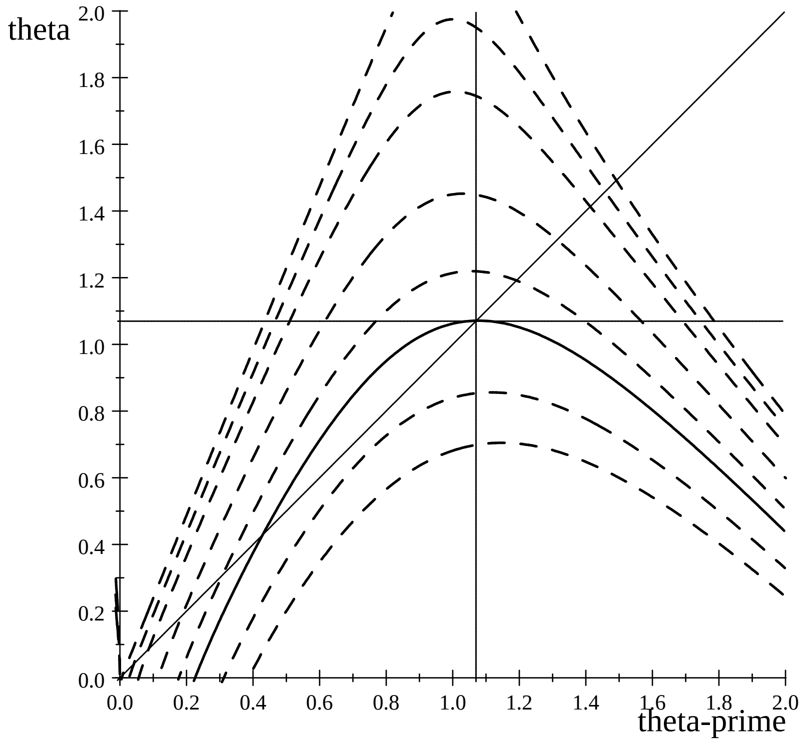

Figure 7

Solving the first-order condition for evolutionary robustness,

$$\left.\frac{\partial v\left(\theta', \theta\right)}{\partial \theta'}\right|_{\theta'=\theta} = 0$$

we obtain

$$\theta = \frac{2\lambda + 6}{3\lambda + 5}$$

This is the evolutionarily robust degree of confidence as a function of one's taste for leisure, see diagram below.

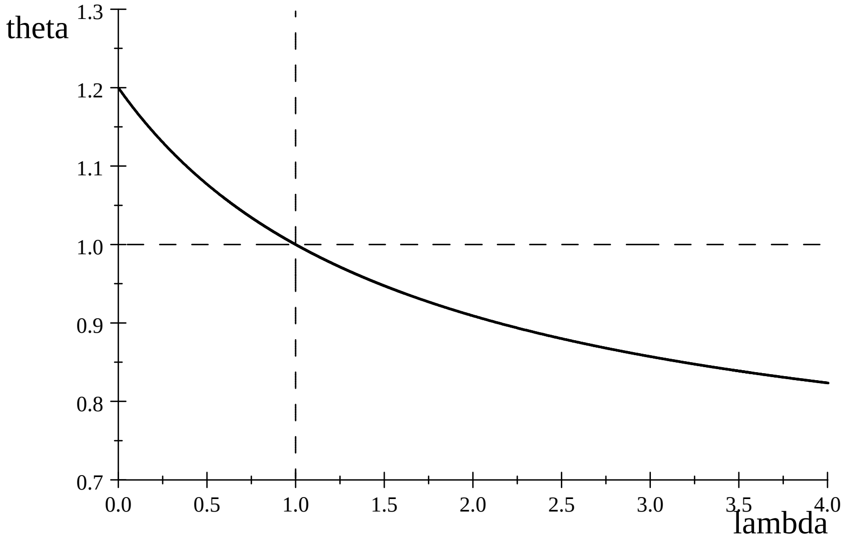

Figure 8.

We note that $\theta > 1$ if and only if $\lambda < 1$. For $\lambda > 1$, overconfidence is a negative asset and hence not selected for. Such entrepreneurs have such a strong taste for leisure that their overconfidence induces them to take out more leisure instead of inspiring them to make more effort. For instance, with $\lambda = 0.5$ as in the earlier graph, we obtain $\theta = 14/13 \approx 1.0769$.

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