COMPETITION AND CULTURE IN THE EVOLUTION OF ECONOMIC BEHAVIOR: A SIMPLE EXAMPLE*

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WP-AD 91-08

* The development of this paper originated in a conversation with Mark Schaffer. I acknowledge helpful conversations with L. Corchón on related literature, as well as financial assistance from the Spanish Ministry of Education, CICYT project no. PB90-0613.

** F. Vega Redondo: IVIE and Universidad de Alicante.

Editor: **Instituto Valenciano de Investigaciones Económicas, S.A.**
Primera Edición Diciembre 1991.
ISBN: 84-7890-676-2
Depósito Legal: V-4088-1991
Impreso por KEY, S.A., Valencia.
Cardenal Benlloch, 69, 46021-Valencia.
Printed in Spain.

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ABSTRACT

Competition tends to promote efficient (equilibrium) behavior through the higher survival of the organizations (say firms) that adopt it. On the other hand, culture (understood as the "inherited" social pattern of behavior) may induce certain short-run inertias. This paper analyzes a dynamic model of the struggle between these two forces in the evolution of alternative stable configurations of an economy's behavior.

1. INTRODUCTION

Let us agree, in this paper, to think of "institutions" as mere coordination devices used by individuals in situations of social and economic interaction. [1] Thus, if these situations are modeled as games, institutions essentially become a selection mechanism for alternative patterns of (equilibrium) behavior. In shaping them, culture, understood as a certain "inherited" pattern of behavior, may be of decisive importance. But culture alone is just one of the components in the process of consolidation of institutions. Efficiency (or optimality) should be another important consideration. If nothing else, because inefficient behavior must suffer the adverse selective forces of whatever degree of competition there exists in the economy.

The purpose of this paper is to study an explicit dynamic process in which both of the preceding aspects of the problem (competition and culture) act as the two blades that cut the eventual shape of institutions. We shall focus in the following very stylized context. The economy is composed of a continuum of organizations (we shall call them firms), each of which consists of the same number of workers playing a certain type of coordination game. This game is a simple version of the kind studied in experiments by van Huyck, Battalio, and Beil [1990]. It has two equilibria: the cooperative and efficient equilibrium; the uncooperative and inefficient one. The key feature of the game is that only the inefficient equilibrium is evolutionarily stable; specifically, this implies that when both cooperative and uncooperative workers co-exist in a firm, the latter are better off than the rest.

[1] This view may be found, for example, in Schotter [1981]. Other less stylized approaches would of course attribute to the general concept of institutions a wider set of possibilities. We shall stay, however, with the first meaning because it seems quite appropriate to motivate our analysis.

Very schematically, competition is formalized by assuming that those firms which do not play efficiently have a relatively lower probability to survive than efficient ones. Culture, on the other hand, is identified with the prevailing social pattern of behavior from which newcomers extract their own in playing the game. Thus, efficiency tends to spread by the operation of the force of selection. Opposing this trend, the fact that, within any heterogeneous group, non-cooperative individual behavior is more profitable than cooperation, tends to increase the frequency of the former through a "contagious" process of imitation. Eventually, these opposing forces will consolidate the particular institutions of the economy, here understood as a culture that remains stable in time.

Depending on the parameters of the model and the initial conditions of the process, either a wholly cooperative or uncooperative stable configuration for the economy will result. As one would expect, the more competitive the environment is (i.e., the stronger the selection forces are), the larger is the set of initial conditions for which the former outcome will result. On the contrary, the wider the "domain of infection" is (specifically, the larger the firms are), the more likely it is that the economy will develop non-cooperative institutions. For a certain range of parameters, there also exists another mixed equilibrium configuration where a positive fraction of individuals exists of each type (cooperative and noncooperative). This equilibrium is, however, sharply unstable.

This paper is mainly intended as a contribution to the recent literature on equilibrium selection in an evolutionary framework. A very partial list from this strand of literature is Selten [1989], Binmore & Samuelson [1990], Fudenberg & Maskin [1990], Foster & Young [1991], and Kandori, Mailath & Rob [1991]. As here, the focus of these papers is on the relationship between optimality (or efficiency) and some sort of long-run viability (evolutionary stability). Although the notion of culture also arises in their contexts, it is much less central there than in the present paper.

Our approach also bears close connection to the important body of literature which studies the role of competition as a source of discipline (i.e., efficiency) in a slack-prone economy. Among others, we may mention Leibenstein [1966], Hart [1983], Selten [1986], or Scharfstein [1988]. Unlike much of this literature, our analysis of this problem is explicitly dynamic. This allows us to analyze the potential key role played by history in consolidating, through cultural inertia, different states of affairs.

Finally, another source of inspiration for this work comes from the biological literature; specifically, from the so-called theory of group selection. The seminal contribution in this literature is Wynne-Edwards [1962] (see also Futuyma [1979]). The main contribution of this literature is to emphasize the possibility that, in some instances, natural selection may operate at the group level rather than at the more orthodox level of the individual organism. This has been proposed by some authors as a way of explaining the seemingly paradoxical evolution of altruistic (but "efficient") behavior in some contexts. Although, in our case, the evolution of efficient behavior would hardly qualify as paradoxical, our approach shares with the theory of group selection the consideration of a two-layer evolutionary process: at the individual level, within a group; at the group level, within the whole economy.

The paper is organized as follows: Section 2 presents the model, Section 3 carries out the analysis, Section 4 ends with a summary. For the sake of smooth discussion, the proofs are relegated to an appendix.

2. THE MODEL

Time is measured discretely, $t = 0,1,2...$ Every period, there is a continuum of agents in the economy which, for simplicity, is taken to be of measure one. They are distributed into groups of m individuals, called firms.

The agents of any given firm play a coordination game with the following characteristics:

(i) Each individual has two possible actions, "work hard" or "shirk" (H or S).
(ii) The game has only two Nash equilibria in pure strategies: "all play H" or "all play S". The first equilibrium Pareto-dominates the second.
(iii) If some agents play H and some S, the latter obtain a higher payoff.

As noted in the Introduction, games with the former characteristics have been explored in experiments by van Huyck *et al* [1990]. They are also stereotypical of those underlying recent Keynesian explanations of unemployment as coordination failures (see Bryant [1983] or Cooper & John [1988]). The following game is a simple particular example of this type.

Each of the players $i = 1,2,\ldots,m$ in a particular firm chooses simultaneously an "effort" $e_i = H,S$. Associated to some given profile $e \equiv (e_1,e_2,\ldots,e_m)$, payoffs $U_i(e)$ are as follows:

$$U_i(e) = x(e) - \frac{1}{2}\,\delta(e_i), \quad i = 1,2,\ldots,m,$$

where:

$$x(e) = 1, \text{ if } e_j = H \text{ for all } j = 1,2,\ldots,m$$
$$= 0, \text{ otherwise;}$$

and

$$\delta(H) = 1, \ \delta(S) = 0.$$

Quite surprisingly at first glance, Van Huyck, Battalio, and Beil find that, in a majority of cases, experimental subjects who are repeatedly (and randomly) grouped to play games similar to that above eventually become "coordinated" in the Pareto-inferior equilibrium.[2] As suggested by Crawford [1991], the theoretical reason for this seems to derive from the fact that only this latter equilibrium is evolutionarily stable, i.e., immune (in

2 Between each stage of play, players were informed of the preceding minimum effort level.

relative terms) to a deviant "mutation".[3] If players were to aim at the Pareto superior equilibrium, any deviant which were to change his action to S would certainly become worse off (this is of course why the aimed configuration is a Nash equilibrium). Nevertheless, such a deviant player would end up being better off in relative terms, i.e., better than the non-deviant players. This source of "strategic uncertainty" seems strong enough in experimental contexts to suck players towards an eventual uniform choice of the inefficient action.

Coming back to our context, it is the precedent considerations that support our following assumption: if any firm ever happens to include a shirker,[4] all other workers will also be led to shirk. For simplicity, we shall assume that such "infection" occurs instantaneously, i.e., within a single period. This will be our simple formulation of the process by which shirking will tend to spread throughout the current population.

On the other side of the coin, the frequency of shirking in the population will tend to decrease because inefficient firms (those employing shirkers) are assumed selected away more rapidly than efficient ones. Specifically, we postulate that every firm operating in any given period is subject to a certain probability of failure. If the firm is of the efficient type (i.e., all its workers work hard) this probability is $p \geq 0$. If this firm

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3 See Maynard Smith & Price [1973] for the original formal proposal of this concept. As formulated by Maynard Smith and Price, the concept applies to infinite populations. For a formulation valid for finite populations (the one relevant in our context of application: each separate firm) see Schaffer [1989].

4 The model would yield equal qualitative conclusions if it were assumed that there must be at least k shirkers (m>k) before the firm is "infected". Notice that if $k \geq 2$ and a firm has at least k shirkers no one of them will find it optimal to shift unilaterally to working hard. However, the hard worker will become better off if, in these circumstances,he unilaterally becomes a shirker.

is instead of the inefficient type (some - in fact all [5] - of its workers shirk), this probability is q. Naturally, $q > p$.

When firms fail, we assume that they also irreversibly disappear, their workers then becoming unemployed. These workers (or their descendants, if we wish to think in terms of a generational structure) enter again the labor force next period, being grouped together in a random fashion to form the same number of firms as previously disappeared. Each of these fresh workers enters his new firm with some new "attitude" or "propensity". Irrespectively of his past experience (or that of his ancestor), we assume that he will have a propensity for H or S with probability equal to the respective frequencies of each of these actions in the current population.[6] This is our schematic formalization of culture (or socialization). Of course, a propensity for H will materialize in this same action only if the worker with this propensity happens to enter a firm where all workers also have it. Otherwise, he will immediately shift to shirking, as explained above.

We now formalize matters. Let $\mu(t)$ and $[1- \mu(t)]$ denote the respective frequencies of high- and low-effort workers present at any given time $t = 0,1,\ldots$ By our assumption that "infection" within a firm is instantaneous, those are also the respective frequencies of efficient and inefficient firms. From our assumption on the survival probabilities of each type, we can rely on the law of large numbers to conclude that there is (a measure of)

$$x(t) \equiv p\cdot\mu(t) + q\cdot[1-\mu(t)] \qquad (1)$$

5 Because of our precedent assumption that any shirking worker infects his co-workers instantaneously, all workers of an inefficient firm will shirk.

6 This could be generalized by assuming that past experience plays a role in determining future choices. The gist of our analysis would still apply as long as the new choice is affected to some extent by the overall social pattern and not merely reproduces the pattern of those firms which failed during the previous period.

individuals who become unemployed at (the end of) period t. These individuals are grouped randomly to form $x(t)/m$ new firms at (the beginning of) period t+1 which, from our formulation of the cultural process of "fresh socialization", consist of:

- a total of $[x(t)/m][\mu(t)]^m$ of efficient firms, and
- a total of $[x(t)/m][1-[\mu(t)]^m]$ of inefficient firms.

The dynamics on $\mu(\cdot)$ - the population frequency of hard-working individuals - implied by the above formulation may be written as follows:

$$\begin{aligned}\mu(t+1) &= \mu(t) - p\cdot\mu(t) + \{(p\cdot\mu(t) + q\cdot[1-\mu(t)])\ [\mu(t-1)]^m\} \\ &= (p-q)\ [\mu(t)]^{m+1} + q\cdot[\mu(t)]^m + (1-p)\mu(t). \qquad (2)\end{aligned}$$

Mere inspection of the above difference equation indicates that both $\mu = 0$ and $\mu = 1$ are equilibria, i.e., stationary points. Thus, both an economy composed of either fully efficient or fully inefficient firms stays unchanged through time. This, however, is not the really interesting question. The important issue is whether these configurations are stable, at least locally. That is, whether they are *asymptotically stable*, in the sense that sufficiently small deviations from these equilibria still lead back to them. An answer to these questions is contained in the following propositions.

Proposition 1: For all p, q, the equilibrium $\mu = 0$ is asymptotically stable.

Proposition 2: The equilibrium $\mu = 1$ is asymptotically stable if, and only if, $\alpha \equiv q/p > m$.

The proof of the above propositions derives from a straightforward investigation of the local features of the function

$$h(\mu) \equiv (p-q)\ \mu^{m+1} + q\ \mu^m + (1-p)\ \mu \qquad (3)$$

at the points $\mu = 0$ and $\mu = 1$. For a global analysis of the system, we shall build upon the following lemmas.

Lemma 1: There exists at most one μ^*, $0 < \mu^* < 1$, such that $h(\mu^*) = \mu^*$.

Lemma 2: Let μ^*, $0 < \mu^* < 1$, satisfy $h(\mu^*) = \mu^*$. Then, $h'(\mu^*) > 1$.

Which then allows us to obtain a full characterization of the problem at both the static and dynamic levels as follows.

Proposition 3: If $\alpha \equiv q/p \leq m$, no interior equilibrium exists. If $\alpha > m$, then one, and only one, interior equilibrium exists, $\mu = \mu^*$, with $0 < \mu^* < 1$.

Proposition 4: If $\alpha \leq m$, $\mu(t) \longrightarrow 0$, for all $\mu(0) < 1$. If $\alpha > m$, $\mu(t) \longrightarrow 1$ when $\mu(0) > \mu^*$, and $\mu(t) \longrightarrow 0$ when $\mu(0) < \mu^*$.

By Proposition 4, if the ratio of survival probabilities α (the "efficiency bite") is smaller than the firm size m (the "infection spread-range"), shirking will eventually predominate if any small fraction of shirkers ever arises. If, on the contrary, $\alpha > m$, both of the end-point equilibria will have an attraction basin of positive measure. The size of these basins is determined by μ^*, the unique interior equilibrium which is itself unstable (i.e., has no attraction basin).

Let $\mu^*(\alpha,m)$ denote the function which reflects the dependence of μ^* on the parameters of the model, α and m. (If $\alpha \leq m$, $\mu^*(\alpha,m) = 1$ by Proposition 4). As stated by the following proposition, the nature of the dependence of $\mu^*(\alpha,m)$ on α and m is as expected.

Proposition 5: If $\alpha > m$, $\dfrac{\partial\mu^*(\alpha,m)}{\partial\alpha} < 0$ and $\dfrac{\partial\mu^*(\alpha,m)}{\partial m} > 0$.

Moreover, $\mu^* \longrightarrow 0$ as $\alpha \longrightarrow \infty$ and $\mu^* \longrightarrow 1$ as $m \longrightarrow \infty$.

3. CONCLUSIONS

The precedent analysis clarifies the sense in which competition struggles with the "infectious" nature of a shirking culture, eventually steering the economy towards alternative stable configurations. In our simple context, there are two of them. In one, shirking eventually predominates; in the other, it is efficient "hard work" which comes to prevail throughout the economy.

The range of initial conditions which lead to each of these outcomes depends on the following two characteristics of the economy:

(i) the harshness of its competition, as measured by the ratio of survival probabilities <u>between</u> efficient and inefficient firms;
(ii) the size of firms, which determines the rate at which shirking spreads throughout the economy by imitation <u>within</u> each firm.

As competition becomes more stringent, or the "domain of infection" more restricted, the range of initial cultures which will eventually consolidate into a fully efficient economy becomes larger. This reflects a dynamic role for competition in overcoming cultural inertias that would otherwise lead the economy towards a predominant shirking culture.

APPENDIX

Proof of Proposition 1:

From (3), we compute $h'(0) = 1$. Thus, the local stability of the system at $\mu = 0$ requires the investigation of higher-order approximations. Rewrite (2) as follows:

$$\mu(t+1) - \mu(t) = q\,([\mu(t)]^m - [\mu(t)]^{m+1}) - p\,(\mu - [\mu(t)]^{m+1}) \tag{4}$$

and denote:

$f(\mu) \equiv p\,(\mu - \mu^{m+1})$, and

$g(\mu) \equiv q\,(\mu^m - \mu^{m+1})$.

Taking limits, we have:

$$\lim_{\mu \to 0} \frac{f(\mu)}{g(\mu)} = \infty, \tag{5}$$

which, in view of (4), leads to the desired conclusion.[7] ∎

Proof of Proposition 2:

We compute:

$$h'(1) = (p-q)(m+1) + q\,m + (1-p) = p\,m - q + 1 \tag{6}$$

which guarantees local stability of $\mu = 1$ if

$$p\,m - q < 0, \tag{7}$$

i.e., $\alpha > m$. If $\alpha = m$, $f'(1) = g'(1)$, and we need to evaluate a second-order approximation. It is immediate to see that in this case, we have

[7] Note that, if $0 \leq m(0) \leq 1$, (2) implies that $0 \leq m(t) \leq 1$ for all t.

$g''(1) < f''(1)$. Therefore, there is some sufficiently small $\varepsilon > 0$ such that, for all μ such that $1-\varepsilon \leq \mu < 1$,

$$g'(\mu) > f'(\mu) \tag{8}$$

and therefore,

$$h(\mu) - \mu > 0, \tag{9}$$

which shows the local instability of $\mu = 1$ in this case. Finally, if $\alpha < m$, (6) implies that $\mu = 1$ is as well unstable. This completes the proof of the proposition. ▮

Proof of the Lemma 1:

From (3), an equilibrium μ^* must satisfy $h(\mu^*) - \mu^* = 0$. Or equivalently, provided that $\mu^* > 0$:

$$\phi(\mu^*) \equiv q\ (\mu^{m-1} - \mu^m) - p\ (1 - \mu^m) = 0. \tag{10}$$

We compute:

$$\phi'(\mu) = ((m-1)\ \mu^{m-2} - m\ \mu^{m-1})\ q - (-m\ \mu^{m-1} p). \tag{11}$$

Denote:

$$\gamma(\mu) \equiv \frac{\phi'(\mu)}{\mu^{m-2}}\ . \tag{12}$$

For all $\mu > 0$, we have:

$$\text{sgn}\ \phi'(\mu) = \text{sgn}\ \gamma(\mu). \tag{13}$$

Moreover, the function γ is linear in μ with negative slope equal to $-\ m\ (q-p)$. Given this linearity of γ, (13) and the fact that $\phi(1) = 0$ imply that only one $\mu^* < 1$ may exist for which $\phi(\mu^*) = 0$. This implies, therefore, that only one $\mu^* < 1$ may exist for which $h(\mu^*) = \mu^*$, completing the proof of the lemma. ▮

Proof of Lemma 2:

From the considerations explained in the proof of Lemma 1, it is clear that if $\mu^* < 1$ and $h(\mu^*) = \mu^*$, we must also have $\gamma(\mu^*) > 0$. Therefore, by (13), $\phi'(\mu^*) > 0$. Since

$$h(\mu) = \phi(\mu)\ \mu + \mu \tag{14}$$

we have:

$$h'(\mu) = \phi(\mu) + \phi'(\mu)\ \mu + 1. \tag{15}$$

Given that $\phi(\mu^*) = 0$, the desired conclusion follows. ∎

Proof of Proposition 3:

Assume $\alpha \le m$. Denote by

$$E \equiv \{\ \mu \in [0,1]\colon h(\mu) = \mu\ \} \tag{16}$$

the set of equilibria, and let

$$\tilde{\mu} \equiv \max \{\ \mu\colon 0 \le \mu < 1\ \&\ \mu \in E\ \} \tag{17}$$

Suppose, for the sake of contradiction, that $\tilde{\mu} > 0$. If $\alpha \le m$, the fact that $f''(1) < g''(1)$ implies (c.f. the proof of Proposition 2) that there exists some $\varepsilon_1 > 0$ such that for all μ such that $1-\varepsilon_1 < \mu < 1$, $f(\mu) > g(\mu)$. Then $\tilde{\mu}$ must satisfy $f'(\tilde{\mu}) > g'(\tilde{\mu})$, which violates Lemma 2.

Consider now the case $\alpha > m$. This inequality implies (see above) that there exists some $\varepsilon_2 > 0$ such that for all μ such that $1-\varepsilon_2 < \mu < 1$, $g(\mu) > f(\mu)$. On the other hand, (5) implies that there exists some $\varepsilon_3 > 0$ such that for all μ such that $0 < \mu < \varepsilon_3$, $f(\mu) > g(\mu)$. Thus, since both f and g are continuous functions, there must be some μ^*, $0 < \mu^* < 1$, for which $f(\mu^*) = g(\mu^*)$. By Lemma 2, such interior equilibrium must be unique. This completes the proof of the Proposition. ∎

Proof of Proposition 4:

If $\alpha \leq m$, it was shown above that $f(\mu) > g(\mu)$ for all $0 < \mu < 1$. Thus, we conclude that $\mu(t) \longrightarrow 0$, for all $\mu(0) < 1$.

Now, let $\alpha > m$. In this case, it was shown in the proof of Proposition 3 that there is a unique interior equilibrium μ^* such that:

$$1 > \mu > \mu^* \implies g(\mu) > f(\mu), \tag{18a}$$

$$\mu^* > \mu > 0 \implies f(\mu) > g(\mu). \tag{18b}$$

This implies that $\mu(t) \longrightarrow 1$ if $\mu(0) > \mu^*$, and $\mu(t) \longrightarrow 0$ if $\mu(0) < \mu^*$. The proof of the proposition is complete. ▮

Proof of Proposition 5:

If $\alpha > m$, Proposition 4 has established the existence of a unique interior equilibrium $\mu^*(\alpha,m)$. This value is implicitly defined by the equation:

$$\alpha\ (\mu^m - \mu^{m+1}) + \mu^{m+1} - \mu = 0 \tag{19}$$

Differentiating this equation with respect to α and rearranging terms, we obtain:

$$\frac{\partial \mu^*(\alpha,m)}{\partial \alpha} = - \frac{\mu^m - \mu^{m+1}}{\alpha\ (m\ \mu^{m-1} - (m+1)\ \mu^m) + (m+1)\ \mu^m - 1}, \tag{20}$$

where the numerator is obviously positive, and the denominator coincides with $g'(\mu) - f'(\mu)$ which, by Lemma 2 is positive. Thus, the overall expression is negative, as claimed.

Differentiating now (19) with respect to m, we obtain:

$$(1-\alpha)\ \mu^m\ \ell n\ \mu + (1-\alpha) \frac{n}{\mu} \frac{\partial \mu^*(\alpha,m)}{\partial m} + \alpha\ \mu^{m-1}\ \ell n\ \mu + \alpha \frac{m-1}{\mu} \frac{\partial \mu^*(\alpha,m)}{\partial m}, \tag{21}$$

which yields:

$$\frac{\partial\mu^*(\alpha,m)}{\partial m} = - \frac{(1-\alpha)\mu^m \,\ell n\mu + \alpha\mu^{m-1} \,\ell n\mu}{(1-\alpha)\frac{n}{\mu} + \alpha\frac{m-1}{\mu}}, \tag{22}$$

where the numerator is negative and the denominator positive. This yields the desired conclusion with respect to the first part of the proposition. The second part, referred to the limits of μ^* as either α or m become arbitrarily large, follows immediately from (19). ∎

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