# Unravelling Conditions for Successful Change Management Through Evolutionary Games of Deterrence

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**Abstract** The paper proposes analyze the conditions for successful change management requiring information transmission and transformation of the information received into change implementation. To that end, starting from an elementary standard matrix game considering only information transmission, the paper will extend the case by considering that stakeholders have to simultaneously take decisions concerning the two above dimensions. A dynamic approach supported by the Replicator Dynamics model will then be proposed, aiming at analyzing asymptotic behaviors. The difficulties often met when trying to solve differential systems will be pointed out. Therefore a new method will be developed, leaning on a bridging in the evolutionary context between standard games and a particular type of qualitative games, called *Games of Deterrence*, and which object is to analyze strategies playability. Through the equivalence between the two types of games, the methodology will enable to remove some question marks in the analysis of asymptotic behaviors, thus contributing to a better understanding of conditions fostering change pervasion, and in particular of the role played by incentives.

**Keywords:** change, deterrence, evolution, incentives, playability, Replicator Dynamics, stability.

## 1. Introduction

The ever increasing pace of ICT development and globalization generates a dramatic shortening of the products' life cycle, which in turn decreases the possibility of sustainable competitive advantages for the firms. Richard D'Aveni (D'Aveni, 1994) has analyzed this phenomenon distinguishing different arenas of hyper-competition. One of the major elements highlighted is the core capacity of managing breakthroughs, in particular through the mastering of timing and knowhow associated with products and services. In this respect, there is no doubt that change management is a core competency for a firm which aim is sustainable development. Now implementation of change management may present a variety of difficulties, among which reluctance to share information and to change (Fichman and Kemener, 1997; Rogers, 1983). The works developed in Experimental Psychology, and especially Kahneman and Tversky's Prospect Theory (Kahneman and Tversky, 1979), have highlighted decision biases like anchoring, procrastination, sensitivity to loss, stubbornness, mirroring, or status quo. All of them may lead the individual under consideration to take inappropriate decisions, which most of the time have as hidden objective to comfort his/her position and hence not accept to change. Whence the necessity for the firm's management to develop an accurate cost-benefit analysis of change versus status quo for each decision maker. As a result of this analysis the firm's management may decide to allocate incentives to the personnel concerned.

A game theoretic model of the issues at stake has already been developed, considering a firm structured in departments, each one having a relative autonomy in terms of information sharing and change adoption (Rudnianski and Tanasescu, 2012). This model has considered several assumptions about the consequences for a department of receiving information relevant from the company's global perspective. The starting point was to consider that a department $i$ can decide to send or not to send to a neighboring department $j$ an information pertaining to a possible change in the conduct of affairs. Similarly, department $j$, when receiving the information, may decide or not to act accordingly and especially to implement change that might be triggered by the information received. At the most elementary level, the problematic can be analyzed through a series of standard 2x2 games in which the players' strategic sets could refer, either to information sending or to change adoption. Various cases have been considered, depending on the respective values for each player of costs, incentives and benefits received from the company's general management. At a second level, the model used the Replicator Dynamics to define conditions under which cooperation between connected departments can prevail. At a third level, the initial model was extended to matrix games in which each party should simultaneously consider whether to send information or not, and whether to adopt changes stemming from the information received or not. A general evolutionary analysis of these games was not performed due to the difficulties to find an analytical solution of the dynamic system. Now this obstacle can be removed, thanks to the results recently found by Ellison and Rudnianski, about the existence of equivalence relations between standard quantitative games and a particular type of qualitative games called *Games of Deterrence* (Ellison and Rudnianski, 2009; Ellison and Rudnianski, 2012). More precisely these equivalence relations enable to translate standard evolutionary games into evolutionary Games of Deterrence which display identical asymptotic properties. In turn, it has been shown (Ellison and Rudnianski, 2012) that the asymptotic properties of these Evolutionary Games of Deterrence may be derived from the playability properties of the players' strategies in the corresponding matrix Games of Deterrence. There is then no need to solve the original dynamic system.

On these bases, the present paper will in a first part recall the results available in the analysis of conditions required for successful change management through the standard game theoretic approach. In a second part, after having recalled the core properties of matrix Games of Deterrence, the paper will develop the equivalences between evolutionary standard games and evolutionary Games of Deterrence. A third part will then use these equivalences to analyze the conditions of success in non-elementary issues of change pervasion. In particular, success of change pervasion will be associated with the playability properties of the Games of Deterrence under consideration.

## 2. Conditions for successful change management through the standard game theoretic approach

The present global context can be characterized as highly dynamic with high failure rates. The continuous increase in the rythm of technological innovations translates into a dramatic shortening of products life cycles and a higher frequency of organizational change. One of the consequences being that the windows of opportunity to make profit from innovation and change open more frequently, but for a shorter time.

In order to overcome these difficulties one idea could be to develop a set of incentives, such that the personnel of the organization accepts and contributes to the implementation of the change.

In this section we start with an elementary model which will help to better understand the context, and then we shall develop the general model of information exchange between two departments.

### 2.1. An introductive elementary example

Let us consider two departments $i$ and $j$ of the firm such that each one can decide to send ($S$) or not to send ($\underline{S}$) information to the other. Let us furthermore assume that for each of the two departments:

- receiving information generates a profit of 3
- sending information generates a cost of 2.

The question is : should a department send information (strategy $S$) or not (strategy $\underline{S}$)? To find the answer, one may resort to a game theoretic approach characterized by the matrix hereunder:

| | S - sending | $\underline{S}$ - not sending |
|---|---|---|
| S - sending | (1,1) | (-2,3) |
| $\underline{S}$ - not sending | (3, -2) | (0,0) |

Fig. 1

It can be easily seen that the game displays a unique Nash equilibrium ($\underline{S}, \underline{S}$). In other words the example shows that despite the fact that the two departments would benefit from information exchange, this exchange cannot occur. In fact, this paradoxical conclusion just reflects the fact that the game is a *Prisonner's Dilemma.* Whence the perpetual question: what conditions could make cooperation prevail and result into information exchange between the two parties?

A possible answer is to develop a set of incentives that will push each department to send information to the other one. In our example, if the company rewards the sending of information by an incentive of 3, the game is then represented by the matrix hereunder:

| | S | $\underline{S}$ |
|---|---|---|
| S | (4,4) | (1,3) |
| $\underline{S}$ | (3, 1) | (0,0) |

Fig. 2

The unique Nash Equilibrium here is $(S, S)$. Thus by the use of incentives the company is sure that information exchange will pervade.

### 2.2. General case: results from a standard approach

Let us generalize the case here above by considering a company's department with $k$ employees, and which wants to implement a change possibly stemming from a technological innovation. Let us furthermore assume that :

– the department's incentives policy is decided by its manager
– the case is symmetric: benefits, incentives and costs resulting from information sharing and change adoption are the same for all employees.
– success is an increasing function of information sharing and the resulting change adoption
– the value for the department of change adoption by $k$ employees is an increasing function of $k$.

Each employee $i$ generating change or possessing relevant information about such change can decide to send or not to send this information to other employees. Likewise each employee $i$ receiving information from employee $j$ can decide to adopt or not to adopt the change made possible through reception of this information.

For each employee $i$ there are four possible sets of actions, which are given by the table hereunder:

| | S | $\underline{\text{S}}$ |
|---|---|---|
| A | SA | $\underline{\text{S}}$A |
| $\underline{\text{A}}$ | S$\underline{\text{A}}$ | $\underline{\text{S}}$ $\underline{\text{A}}$ |

Fig. 3

For employee $i$, the results of the different possible interactions with employee $j$ are given by the following table:

| Employee $i$ | Benefit | Cost | Incentive |
|---|---|---|---|
| Sending information to $j$ | $b^s$ | $c^s$ | $\beta^s$ |
| Not sending information to $j$ | $b^n$ | $c^n$ | $\beta^n$ |
| Adopting change | $b^a$ | $c^a$ | $\beta^a$ |
| Not adopting change | 0 | 0 | 0 |

Fig. 4

This means that for employee $i$, the payoff resulting from:

– sending an information to another employee, is: $s = \beta^s + b^s - c^s$
– not sending information, is: $n = b^n - c^n$
– adopting change made possible by the information received from another employee, is:$a = (\beta^n + b^n - c^n)$. In case employee $j$ doesn't send information, the result for employee $i$ of adopting is the same than the result of not adopting.
– not adopting change made possible by the information received from another employee, is 0. Of course this is just an assumption. One could consider situations in which not adopting is associated with a non-zero payoff, for instance a negative one, meaning that by adopting this attitude employee $i$ is a loser.

We shall follow two approaches:

– the static one based on non-repeated standard matrix games
– the dynamic one based on the Replicator Dynamics.

### 2.3. Static Approach

The starting point is the matrix of table 2.3.

| | SA | S$\underline{\mathrm{A}}$ | $\underline{\mathrm{S}}$A | $\underline{\mathrm{SA}}$ |
|---|---|---|---|---|
| SA | (a+s,a+s) | (a+s,s) | (s, a+n) | (s,n) |
| S$\underline{\mathrm{A}}$ | (s,s+a) | (s,s) | (s, a+n) | (s,n) |
| $\underline{\mathrm{S}}$A | (a+n,s) | (a+n,s) | (n,n) | (n,n) |
| $\underline{\mathrm{SA}}$ | (n,s) | (n,s) | (n,n) | (n,n) |

Fig. 5

| | Conditions | | | Nash Equilibria |
|---|---|---|---|---|
| A1 | $a > 0$ | $n < s < n + a < s + a$ | $s > n$ | (SA,SA) |
| A2 | | $n < n + a < s < s + a$ | | |
| A3 | | $s < s + a < n < n + a$ | $s < n$ | ($\underline{\mathrm{S}}$A,$\underline{\mathrm{S}}$A), ($\underline{\mathrm{SA}}$,$\underline{\mathrm{SA}}$),($\underline{\mathrm{S}}$A,$\underline{\mathrm{SA}}$),($\underline{\mathrm{SA}}$,$\underline{\mathrm{S}}$A) |
| A4 | | $s < n < s + a < n + a$ | | |
| B1 | $a < 0$ | $n + a < s + a < n < s$ | $s > n$ | ( S$\underline{\mathrm{A}}$, $\underline{\mathrm{SA}}$) |
| B2 | | $n + a < n < s + a < s$ | | |
| B3 | | $s + a < s < n + a < n$ | $s < n$ | ($\underline{\mathrm{S}}$A,$\underline{\mathrm{S}}$A), ($\underline{\mathrm{SA}}$,$\underline{\mathrm{SA}}$),($\underline{\mathrm{S}}$A,$\underline{\mathrm{SA}}$),($\underline{\mathrm{SA}}$,$\underline{\mathrm{S}}$A) |
| B4 | | $s + a < n + a < s < n$ | | |

Fig. 6

To analyze the corresponding game, we need to compare and order the values of $n$, $s$, $n + a$ and $s + a$. It can be easily seen that 8 cases need to be distinguished, each one associated with a specific set of Nash equilibria (see table 2.3. here below):
It follows from the above table that change will pervade if the following two quite common sense conditions are satisfied :

- Adoption provides a benefit
- Sending information relative to change provides a payoff superior to the one stemming from not sending that information.

Thus the value of adoption should be positive and independent from the decision to send or not to send information.

## 2.4. Recalling the core properties of the Replicator Dynamics

The Replicator Dynamics is a classical dynamic system describing the evolution of a population broken down into several species. The outcome of the interaction between two individuals is given by a symmetric matrix game $G$.

Let us consider a population comprised of $n$ species $1, 2, \ldots, n$, each one characterized by a particular behavior. Let $\theta = (\theta_1, \theta_2, \ldots, \theta_n)$ define the population's profile, i.e. the proportion of each species in the population. Individuals may interact, whether they belong to the same species or not. The payoffs resulting from these interactions are given by a matrix. Thus, with any pair $(i, j)$ of interacting individuals, one can associate a pair $(u_{ij}, v_{ij})$ of payoffs. Let furthermore:

- $u_i = \sum\limits_k \theta_k u_{ik}$ define the fitness of species $i$
- $u_T = \sum\limits_i \theta_i u_i$ define the fitness of the population.

The Replicator Dynamics is then defined by the following system of differential equations:

$$\forall i \in \{1, 2, \ldots, n\}, \theta_i' = \theta_i(u_i - u_T)$$

According to this system, the evolution of the proportion $\theta_i$ of species $i$ in the entire population depends on its fitness with respect to the population's fitness: if the fitness of $i$ is greater than the population's fitness, then the proportion of species $i$ in the population will increase, while on the opposite if $i$'s fitness is smaller than the average fitness of the population, then the proportion of species $i$ will decrease.

It can be seen from the above set of equations that he Replicator Dynamics does not take into account the possibility for new species to emerge during the evolution. This means between other things that all species present at time $t$, whatever that time is, were already present in the population at initial time.

Last, let us note that if $\theta$ represents the space of population's profiles, and $f$ is a vector field on $\theta$ such that $\theta = f(\theta)$ with $f_i(\theta) = \theta_i(u_i - u_T)$, an equilibrium of the Replicator Dynamics is then defined as a fixed point of $f$.

### 2.5. The dynamic approach of change

It then stems from table 2.3. that the average payoffs associated with the various strategies are given by the following set of equations :

$$\begin{cases} u_{SA} = a(\theta_{SA} + \theta_{S\underline{A}}) + s \\ u_{S\underline{A}} = s \\ u_{\underline{S}A} = a(\theta_{SA} + \theta_{S\underline{A}}) + n \\ u_{\underline{SA}} = n \\ u_T = a(\theta_{SA} + \theta_{S\underline{A}})(\theta_{SA} + \theta_{\underline{S}A}) + s(\theta_{SA} + \theta_{S\underline{A}}) + n(\theta_{\underline{S}A} + \theta_{\underline{SA}}) \end{cases}$$

Whence:

$$\begin{cases} u_{SA} - u_T = a(\theta_{SA} + \theta_{S\underline{A}})(\theta_{SA} + \theta_{\underline{SA}}) + (s-n)(\theta_{\underline{S}A} + \theta_{\underline{SA}}) \\ u_{S\underline{A}} - u_T = -a(\theta_{SA} + \theta_{S\underline{A}})(\theta_{SA} + \theta_{\underline{S}A}) + (s-n)(\theta_{\underline{S}A} + \theta_{\underline{SA}}) \\ u_{\underline{S}A} - u_T = a(\theta_{SA} + \theta_{S\underline{A}})(\theta_{SA} + \theta_{\underline{S}A}) - (s-n)(\theta_{SA} + \theta_{S\underline{A}}) \\ u_{\underline{SA}} - u_T = -a(\theta_{SA} + \theta_{S\underline{A}})(\theta_{SA} + \theta_{\underline{S}A}) - (s-n)(\theta_{SA} + \theta_{S\underline{A}}) \end{cases}$$

The above system of equations enables to categorize the cases to be considered, as indicated on table 2.5. hereunder.

| | | | $u_{SA} - u_T$ | $u_{S\underline{A}}$ | $u_{\underline{S}A} - u_T$ | $u_{\underline{SA}} - u_T$ |
|---|---|---|---|---|---|---|
| A1,A2 | $a > 0$ | $s > n$ | $+$ | ? | ? | $-$ |
| A3,A4 | | $s < n$ | ? | $-$ | $+$ | ? |
| B1,B2 | $a < 0$ | $s > n$ | ? | $+$ | $-$ | ? |
| B3,B4 | | $s < n$ | $-$ | ? | ? | $+$ |

Fig. 7

So we see that the relatively coarse granularity of the available information does not enable to determine precisely the evolution of behaviors.

## 3. The Games of Deterrence approach

Games of Deterrence consider only two possible states of the world:

- those which are acceptable for the player under consideration (noted 1)
- those which are unacceptable for that same player (noted 0)

Each player's objective is to be in an acceptable state of the world. Therefore, Games of Deterrence will not look for optimal strategies but for strategies that the player under consideration can play, and which will therefore be called playable strategies.

### 3.1. Recalling core properties of matrix Games of Deterrence

Let $E$ and $R$ be two players with respective strategic sets $S_E$ ($|S_E| = n$) and $S_R$ ($|S_R| = p$). Given any strategic pair $(i, k) \in S_E \times S_R$, let:

- $(u_{ik}, v_{ik})$ be the corresponding binary outcome pair
- $U$ and $V$ be the sets of binary outcome pairs of the two players associated with the set of possible strategic pairs

A strategy $i$ of $E$ is said to be *safe* iff $\forall k \in S_R, u_{ik} = 1$. A strategy which is not safe will be termed *dangerous*.

Given $i \in S_E$, let $J_E(e_i)$ be strategy $i$'s positive playability index defined as follows:

- If i is safe, then $J_E(i) = 1$
- If not $J_E(i) = (1-j_E)(1-j_R) \prod_{k \in S_R} [1-J_R(k)(1-u_{ik})]$, with $j_E = \prod_{i \in S_E} (1-J_E(i))$ and $j_R = \prod_{k \in S_R} (1 - J_R(k))$

If $J_E(i) = 1$, strategy $i \in S_E$ is said to be *positively playable*. If there are no positively playable strategies in $S_E$, that is if $j_E = 1$, all strategies $i \in S_E$ are said to be *playable by default*. A strategy in $S_E \cup S_R$ is *playable* iff it is either positively playable or playable by default.

The system $P$ of all equations of $J_E(i), i \in S_E$, $J_R(k), k \in S_R$, $j_E$ and $j_R$ is called *the playability system* of the game. The playability system $P$ may be considered as a dynamic system $J = \hat{f}(J)$ on the playability set. A *solution* of the matrix Game of Deterrence is a fixed point of $\hat{f}$. It has been shown (Fichman and Kemener, 1997) that any matrix Game of Deterrence has at least one solution.

Given a strategic pair $(i, k) \in S_E \times S_R$, $i$ is said to be *deterrent* vis-a-vis $k$ iff the three following conditions apply:

- $i$ is playable
- $v_{ik} = 0$
- $\exists k' \in S_R : J_R(k') = 1$

It has been shown (Fichman and Kemener, 1997) that a strategy $k \in S_R$ is playable iff there is no strategy $i \in S_E$ deterrent vis-a-vis $k$. Thus, the study of deterrence amounts to analyzing the strategies' playability properties

A *symmetric Game of Deterrence* is a Game of Deterrence $(S_E, S_R, U, V)$ such that $S_E = S_R$ and $U = V^t$ (i.e. $\forall (i, k) \in S_E^2, u_{ik} = v_{ki}$). In the case of symmetric games, the strategic set will be noted $S$.

A *symmetric solution* is a solution in which $\forall i \in S, J_E(i) = J_R(i)$. It has been shown (D'Aveni, 1994) that in a symmetric Game of Deterrence, $j_E = j_R$

### 3.2. Evolutionary Games of Deterrence

It has been shown (Ellison and Rudnianski, 2009) that for a symmetric Game of Deterrence $G$ with playability system $P$ and Replicator Dynamics $D(G)$, if:

- $P$ has a symmetric solution for which no strategy is playable by default
- at $t = 0$, the proportion of each positively playable strategy is greater than the sum of the proportions of the non-playable strategies,

then:

- the proportion of each non-playable strategy decreases exponentially towards zero
- the proportion of each playable strategy has a non-zero limit

This result can be interpreted as follows: each symmetric solution of the playability system is associated with an Evolutionarily Stable Equilibrium Set of the Replicator Dynamics, i.e. a set of equilibria such that the union of the attraction basins of all the equilibria is a neighbourhood of the set.

### 3.3. Bridging Games of Deterrence with standard games

Two strategies $i$ and $j$ are equivalent if $\forall k \in S, u_{ik} = u_{jk}$.

If $i$ and $j$ are equivalent, then:

1. $\frac{\theta_i}{\theta_j}$ is constant in very solution of the Replicator Dynamics
2. $i$ and $j$ have the same playability in every solution of the playability system.

The case analyzed in section 2.2. has shown that the analysis of standard evolutionary games properties may not always be successful, while on the opposite section 3.2. here above has displayed a significant set of results concerning evolutionary properties of Games of Deterrence. Moreover a correspondance has been established between evolutionary standard games and evolutionary Games of Deterrence (Ellison and Rudnianski, 2012).

More precisely, let:

- Let $\widetilde{G}$ be a symmetric matrix game
- $M$ and $m$ be respectively the maximal and minimal payoffs in $\widetilde{G}$
- $G$ the game derived from $\widetilde{G}$ by:
  - applying the affine transformation which replaces every payoff $u$ by $(u - m)/(Mm)$.
  - for any strategic pair $(p, q)$ such that $v_pq = z$ with $0 < z < 1$, splitting species $p$ into two sub-species $p_1$ and $p_2$ differing only by the fact that $v_{p_1q} = 1$ while$v_{p_q} = 0$, and with respective proportions $z$ and $1 - z$ within species $p$.

It has been proved that [ibid] that if the solution set of $G$ has the properties described in section 3,2 here above, then:

- the proportion of each strategy of $\widetilde{G}$ corresponding to a non-playable strategy in $G$ decreases exponentially towards 0
- the proportion of each strategy of $\widetilde{G}$ corresponding to a playable strategy in G has a non-zero limit.

In other words the asymptotic properties of the dynamic system $D(\widetilde{G})$ can be determined through analyzing the playability system associated with $G$.

## 4. Application to change pervasion

Let us transform the standard game matrix of Fig. 5 into a binary matrix on the basis of the affine transformation introduced in section 3.3. Between other things, this transformation enables to gather the 8 cases of table 6 into 4 groups of two, each one being characterized by a specific pair (minimum, maximum), as shown on table 8.

Let us consider two cases belonging to the same group, for instance A1 and A2. The minimum and the maximum being the same in the two cases, after application of the affine transformation, the distribution of 0s and 1s will also be the same. What may differ is the distribution of non-binary payoffs. But it stems from the method defined in section 3.3, that the strategy of the other player associated with each non binary number can be replaced by two strategies generating respectively payoffs 1 and 0, and differing only by their proportion. As this proportion doesn't intervene in the resulting binary matrix supporting the game of deterrence, the matrix will be the same in the two cases, and so will be the conclusions concerning the strategies' playabilities. Now such invariance property doesn't apply to two cases such that the minimum in one case is the maximum in the other case and vice-versa. Indeed, by definition, unlike for two cases belonging to the same group, the 0s and 1s in the matrices will not be the same. Thus if we consider for instance cases A1 and B3, we see that the payoff pair associated with strategic pair (SA, SA) is (1, 1) in case A1 and (0,0) in case A3. So, on the whole we have to analyze four cases corresponding each one to a specific pair of extremal values.

*CASE A1, A2:* $a > 0$ and $s > n$

Let us for instance consider the case A1 as defined on table 2.3.. The maximum payoff is $s + a$, and the minimum payoff is $n$. We decrease each member of the matrix by $n$ thus fixing the minmum to 0. If we apply the affine transformation and let $x = a/(a + s - n)$ and $y = (s - n)/(a + s - n)$, we then get the matrix of figure 4. hereunder.

| | SA | $S\underline{A}$ | $\underline{S}A$ | $\underline{SA}$ |
|---|---|---|---|---|
| SA | (1,1) | (1,y) | (y,x) | (y,0) |
| $S\underline{A}$ | (y, 1) | (y,y) | (y,x) | (y,0) |
| $\underline{S}A$ | (x,y) | (x,y) | (0,0) | (0,0) |
| $\underline{SA}$ | (0, y) | (0, y) | (0,0) | (0,0) |

Fig. 8

Let us first consider the strategic pair $(SA, \underline{A})$. Here $z = y$ with $0 < y < 1$. Everything else being the same, we can then split species $SA$ into two sub-species $SA1$ and $SA2$ such that the respective proportions of sub-species $SA1$ and $SA2$ in $SA$ are $y$ and $1y$. Let us then consider the strategic pair $(SA, SA)$. Here $z = x$ with $0 < x < 1$. We now can split $SA1$ into $SA11$ and $SA12$, and $SA2$ into $SA21$ and $SA22$.

Likewise:

- $S\underline{A}$ can be replaced by $S\underline{A}11, S\underline{A}12, S\underline{A}21, S\underline{A}22$
- $\underline{S}A$ can be replaced by $\underline{S}A1, \underline{S}A2$
- $\underline{SA}$ can be replaced by $\underline{SA}1, \underline{SA}2$

| | SA11 | SA12 | SA21 | SA22 | S$\underline{A}$11 | S$\underline{A}$12 | S$\underline{A}$21 | S$\underline{A}$22 | $\underline{S}$A1 | $\underline{S}$A2 | $\underline{SA}$1 | $\underline{SA}$2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA11 | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (0,1) | (1,0) | (0,0) |
| SA12 | (1,1) | (1,1) | (1,1) | (1,1) | (1,0) | (1,0) | (1,0) | (1,0) | (1,1) | (0,1) | (1,0) | (0,0) |
| SA21 | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,0) | (0,0) | (1,0) | (0,0) |
| SA22 | (1,1) | (1,1) | (1,1) | (1,1) | (1,0) | (1,0) | (1,0) | (1,0) | (1,0) | (0,0) | (1,0) | (0,0) |
| S$\underline{A11}$ | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1,1) | (0,1) | (1,1) | (0,1) | (1,1) | (0,1) | (1,0) | (0,0) |
| S$\underline{A12}$ | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1,0) | (0,0) | (1,0) | (0,0) | (1,1) | (0,1) | (1,0) | (0,0) |
| S$\underline{A21}$ | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1,1) | (0,1) | (1,1) | (0,1) | (1,0) | (0,0) | (1,0) | (0,0) |
| S$\underline{A22}$ | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1,0) | (0,0) | (1,0) | (0,0) | (1,0) | (0,0) | (1,0) | (0,0) |
| $\underline{S}$A1 | (1,1) | (1,1) | (0,1) | (0,1) | (1,1) | (1,1) | (0,1) | (0,1) | (0,0) | (0,0) | (0,0) | (0,0) |
| $\underline{S}$A2 | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) |
| $\underline{SA1}$ | (0, 1) | (0, 1) | (0, 1) | (0, 1) | (0, 1) | (0, 1) | (0, 1) | (0, 1) | (0,0) | (0,0) | (0,0) | (0,0) |
| $\underline{SA2}$ | (0, 0) | (0, 0) | (0, 0) | (0, 0) | (0, 0) | (0, 0) | (0, 0) | (0, 0) | (0,0) | (0,0) | (0,0) | (0,0) |

Fig. 9

Whence the new binary matrix:

It can be established that the game displays a solution in which strategies $SA_{11}$, $SA_{12}$, $SA_{21}$, $SA_{22}$ are positively playable, and all other strategies are non playable. Hence, if at $t = 0$, the proportion of each positively playable strategy is greater than the proportions of the positively playable strategies tend toward a non âĂŞzero limit, while the proportions of the non-playable strategies tend toward 0. In terms of change analysis, this means that change will pervade through selection by more and more employees of the decisions to send information and to adopt the changes possibly stemming from information received. Thus the conclusion confirms the one already reached with the standard approach, according to which the proportion of employees who will send and adopt increases, while the proportion of those who neither send nor adopt decreases. But the conclusion goes one step further. While the standard approach led to a question mark with respect to the two intermediate behaviors (send but not adopt and not send but adopt), we see here that, every thing else being the same, those two behaviors will vanish with time.

*CASE A3,A4:* $a > 0$ and $n > s$

Let us for instance consider case A3.. By applying the same method than in case A1, we get the matrix of figure 4.:

| | SA | S$\underline{A}$ | $\underline{S}$A | $\underline{SA}$ |
|---|---|---|---|---|
| SA | (x,x) | (x,0) | (0,1) | (0,y) |
| S$\underline{A}$ | (0,x) | (0,0) | (0,1) | (0,y) |
| $\underline{S}$A | (1, 0) | (1, 0) | (y,y) | (y,y) |
| $\underline{SA}$ | (y, 0) | (y, 0) | (y,y) | (y,y) |

Fig. 10

In turn, by breaking down the species into sub-species when necessary, we get the matrix of figure 4.:

| | SA11 | SA12 | SA21 | SA22 | S$\underline{A}$11 | S$\underline{A}$12 | S$\underline{A}$21 | S$\underline{A}$22 | $\underline{S}$A1 | $\underline{S}$A2 | $\underline{SA}$1 | $\underline{SA}$2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA11 | (1,1) | (1,1) | (0,1) | (0,1) | (1,0) | (1,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,1) | (0,1) |
| SA12 | (1,1) | (1,1) | (0,1) | (0,1) | (1,0) | (1,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,0) | (0,0) |
| SA21 | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,1) | (0,1) |
| SA22 | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,0) | (0,0) |
| S$\underline{A}$11 | (0,1) | (0,1) | (0,1) | (0,1) | (0,0) | (0,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,1) | (0,1) |
| S$\underline{A}$12 | (0,1) | (0,1) | (0,1) | (0,1) | (0,0) | (0,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,0) | (0,0) |
| S$\underline{A}$21 | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,1) | (0,1) |
| S$\underline{A}$22 | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,0) | (0,0) |
| $\underline{S}$A1 | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1,1) | (0,1) | (1,1) | (0,1) |
| $\underline{S}$A2 | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1,0) | (0,0) | (1,0) | (0,0) |
| $\underline{SA1}$ | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1,1) | (0,1) | (1,1) | (0,1) |
| $\underline{SA2}$ | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1,0) | (0,0) | (1,0) | (0,0) |

Fig. 11

It can be seen that the game of deterrence associated with the above matrix displays a solution in which $\underline{S}A_1$ and $\underline{S}A_2$ are positively playable and all other strategies are not playable. If at initial the proportions of $\underline{S}A_1$ and $\underline{S}A_2$ are greater than the sum of proportions of the non playable strategies, then it stems from the properties recalled in section 3.2, that the dynamics tends toward a limit for which all employees will decide to adopt but not to send. If we compare that conclusion, with the one obtained through the standard approach, we see that the game of deterrence approach has enabled to remove the question marks about the evolution. The result seems to be paradoxical at first sight. Indeed how can people decided not to send information, when they want in turn to adopt the changes possibly stemming from the information they receive?

The answer simply stems from the characteristics of the case: while change adoption brings a benefit ($a > 0$), the payoff resulting from not sending information is greater than the one resulting from sending. Somehow, the structure considered for the model provides an arbitration between two possible results. Undoubtedly, to foster change adoption, the management plays a crucial role. Indeed by allocating appropriate incentives to the employees when they send information, the management can efficiently change the attitude of the personnel in that respect, with the result that the situation switches from case A3 to case A1, for which change is adopted.

*CASE B1,B2:* $a < 0$ and $n > s$

Adopting the previous notations and proceeding to the affine transformation leads to the following matrix (Figure 4. ).

| | $SA$ | $S\underline{A}$ | $\underline{S}A$ | $\underline{SA}$ |
|---|---|---|---|---|
| $SA$ | (x,x) | (x,1) | (1,0) | (1,y) |
| $S\underline{A}$ | (1,x) | (1,1) | (1,0) | (1,y) |
| $\underline{S}A$ | (0,1) | (0,1) | (y,y) | (y,y) |
| $\underline{SA}$ | (y, !) | (y, !) | (y,y) | (y,y) |

Fig. 12

In turn, by breaking down the species when necessary, we get the matrix of figure 4. hereunder.

| | $SA11$ | $SA12$ | $SA21$ | $SA22$ | $S\underline{A}11$ | $S\underline{A}12$ | $S\underline{A}21$ | $S\underline{A}22$ | $\underline{S}A1$ | $\underline{S}A2$ | $\underline{SA}1$ | $\underline{SA}2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SA11$ | (1,1) | (1,1) | (0,1) | (0,1) | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (1,1) | (1,1) |
| $SA12$ | (1,1) | (1,1) | (0,1) | (0,1) | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (1,0) | (1,0) |
| $SA21$ | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (1,1) | (1,1) |
| $SA22$ | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (1,0) | (1,0) |
| $S\underline{A}11$ | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,0) | (1,0) | (1,1) | (1,1) |
| $S\underline{A}12$ | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,1) | (1,0) | (1,0) | (1,0) | (1,0) |
| $S\underline{A}21$ | (1,0) | (1,0) | (1,0) | (1,0) | (1,1) | (1,1) | (1,1) | (1,1) | (1,0) | (1,0) | (1,1) | (1,1) |
| $S\underline{A}22$ | (1,0) | (1,0) | (1,0) | (1,0) | (1,1) | (1,1) | (1,1) | (1,1) | (1,0) | (1,0) | (1,0) | (1,0) |
| $\underline{S}A1$ | (0,1) | (0,1) | (0,1) | (0,1) | (0,1) | (0,1) | (0,1) | (0,1) | (1,1) | (0,1) | (1,1) | (0,1) |
| $\underline{S}A2$ | (0,1) | (0,1) | (0,1) | (0,1) | (0,1) | (0,1) | (0,1) | (0,1) | (1,0) | (0,0) | (1,0) | (0,0) |
| $\underline{SA}1$ | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1,1) | (0,1) | (1,1) | (0,1) |
| $\underline{SA}2$ | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1, 1) | (0, 1) | (1,0) | (0,0) | (1,0) | (0,0) |

Fig. 13

In the associated Game of Deterrence, strategies $S\underline{A}11$, $S\underline{A}12$, $S\underline{A}21$ and $S\underline{A}22$ are safe, hence positively playable, while all other strategies are not playable. It follows that in this case, provided that the initial profile of the employees population satisfies the condition stated in section 3.2, the employees will choose to send information but not adopt the change that might possibly stem from the information they receive. This conclusion is consistent with the fact that sending information is more rewarding than not sending, while on the opposite adoption generates a loss. It is also consistent with the conclusion obtained in the standard approach, and enable again to remove the question marks to which the standard analysis has led.

*CASE B3,B4:* $a < 0$ and $n < s$

Applying again the previous method leads first the matrix of figure 4. and then to the matrix of figure 4..

| | SA | $S\underline{A}$ | $\underline{S}A$ | $\underline{SA}$ |
|---|---|---|---|---|
| SA | (0,0) | (0, y) | (y,x) | (y,1) |
| $S\underline{A}$ | (y,0) | (y,y) | (y,x) | (y,1) |
| $\underline{S}A$ | (x,y) | (x,y) | (1,1) | (1,1) |
| $\underline{SA}$ | (1, y) | (1, y) | (1,1) | (1,1) |

Fig. 14

| | SA11 | SA12 | SA21 | SA22 | $S\underline{A}11$ | $S\underline{A}12$ | $S\underline{A}21$ | $S\underline{A}22$ | $\underline{S}A1$ | $\underline{S}A2$ | $\underline{SA1}$ | $\underline{SA2}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA11 | (0,0) | (0,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,1) | (0,1) | (1,1) | (0,1) | (1,1) | (0,1) |
| SA12 | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (1,1) | (0,1) | (1,1) | (0,1) |
| SA21 | (0,0) | (0,0) | (0,0) | (0,0) | (0,1) | (0,1) | (0,1) | (0,1) | (1,0) | (0,0) | (1,1) | (0,1) |
| SA22 | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (0,0) | (1,0) | (0,0) | (1,1) | (0,1) |
| $S\underline{A11}$ | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1,1) | (0,1) | (1,1) | (0,1) | (1,1) | (0,1) | (1,1) | (0,1) |
| $S\underline{A12}$ | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1,0) | (0,0) | (1,0) | (0,0) | (1,1) | (0,1) | (1,1) | (0,1) |
| $S\underline{A21}$ | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1,1) | (0,1) | (1,1) | (0,1) | (1,0) | (0,0) | (1,1) | (0,1) |
| $S\underline{A22}$ | (1, 0) | (0, 0) | (1, 0) | (0, 0) | (1,0) | (0,0) | (1,0) | (0,0) | (1,0) | (0,0) | (1,1) | (0,1) |
| $\underline{S}A1$ | (1,1) | (1,1) | (0,1) | (0,1) | (1,1) | (1,1) | (0,1) | (0,1) | (1,1) | (1,1) | (1,1) | (1,1) |
| $\underline{S}A2$ | (1,0) | (1,0) | (0,0) | (0,0) | (1,0) | (1,0) | (0,0) | (0,0) | (1,1) | (1,1) | (1,1) | (1,1) |
| $\underline{SA1}$ | (1, 1) | (1, 1) | (1, 1) | (1, 1) | (1, 1) | (1, 1) | (1, 1) | (1, 1) | (1,1) | (1,1) | (1,1) | (1,1) |
| $\underline{SA2}$ | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1, 0) | (1,1) | (1,1) | (1,1) | (1,1) |

Fig. 15

In the associated Game of Deterrence, strategies $\underline{SA}1$ and $\underline{SA}2$ are safe, hence positively playable, and all other strategies are non-playable. If the condition on the initial population's profile is satisfied, then with time the whole population of employees will choose not to send information and not to adopt change possibly stemming from the information they receive. Again this conclusion is consistent with both the conclusion of the standard approach and the assumptions according to which the payoff for adoption is negative and not sending information is more rewarding than sending. Likewise we see that the conclusion obtained through the evolutionary Games of Deterrence approach enables to remove question marks to which the standard approach led.

## 5. Conclusion

Starting from an elementary representation of change pervasion through information transmission, the paper has first shown that the issue could be seen as a Prisoner's Dilemma : while it would be in the common interest of all parties to exchange information, this exchange can't take place due to exchange information, such exchange can't take place dude to the cost-benefit structure. The paper has then extended the issue to the case where information received might be used to adopt change, situation in which employees have to take simultaneously two decisions: to send or not send information to other employees, and to adopt or not to adopt change that could possibly stem from the information received. It has been shown that incentives play a crucial role in change pervasion. From a more technical point of view, the paper has extended the static approach to a dynamic one, supported by the Replicator Dynamic. It has been shown that in some cases, the difficulties of determining the asymptotic properties of the system within the framework of standard evolutionary games, did not allow conclusions about change pervasion. To solve that difficulty it has been proposed to use the results of recent research work bridging standard evolutionary games with evolutionary Games of Deterrence, for which the determination of asymptotic properties doesn't require the resolution of the dynamic system, but can be based only on the playability properties of the players' strategies. This bridging has enabled to draw conclusions that could not be found through the standard approach. Nevertheless, there is still place for improvement. On the one hand the condition about the initial population's profil is quite strong, and one may ask whether it would be possible to alleviate it in order to extend the field of application. On the other hand, the condition about existence of solutions with no playable by default strategies also limits the field of application. But at the same time it paves the way for future work based on an extension of the games of deterrence used here, i.e. fuzzy games of deterrence in which the playability indices may take any value comprise between 0 and 1.

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