Management by exception in a team: an illustrative analysis*

Marco Alderighi
Università della Valle d'Aosta - Strada dei Cappuccini 2A, 11100 Aosta, Italy
Bocconi University - Via Sarfatti 12, 20120 Milano, Italy
E-mail: m.alderighi@univda.it; marco.alderighi@unibocconi.it

Abstract

We analyse two team coordination procedures, usually referred to as 'management by exception' that allow a firm to exploit most of the coordination advantages in team decision making, while simultaneously limit the costs borne from information acquisition and processing. The results of the model are also discussed in relation to the recent development of information and communication technologies.

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1 Introduction

The design of the information system has become a critical factor for the success of many firms. There are many examples of firms' poor performance due to lack of data, background information and communication, as well as due to an excess of these. In the former, firms are unable to react swiftly to changing markets, while, in the latter, they suffer high costs of implementation and maintenance. With respect to this aspect, a firm's organization design consists of deciding how much information to collect and how to process it.

In this paper, we model a situation where a production-led firm (Carter, 1995) is a team composed of different sale units or shops, and of one production unit, all coordinated by managers whose goals are aligned to the objectives of the firm. Each shop operates in an independent market where demand is uncertain. Sales managers can improve their knowledge about their market conditions by gathering information, which will be used by the production manager to arrange and coordinate the production. Shop information consists of a signal correlated to the market demand, whose precision is determined by the information acquisition expenditure.

Before the realization of market demands, the production manager makes a decision concerning whether or not to modify the level of a production-related variable (e.g. an input of the production process, the capital), which affects the optimal production scale of the firm, and therefore the profits. In fact, the higher (lower) the demand, the higher (lower) the quantity that is optimal to produce, and the larger (smaller) the optimal scale.

The decision-making problem of the production manager rests on the fact that the firm suffers a loss in rearranging the production (i.e. there is a cost in processing the information to choose the optimal scale), as well as in choosing the wrong scale. To minimize the overall costs, the firm can limit the re-scaling of the production to those situations where it is more needed (exceptional situations), and to maintain a predetermined scale when it is less required (ordinary situations).

This team coordination practice is usually referred to as 'management by exception' (Marschak and Radner, 1972: Chapter 6, Sections 11 and 12, hereafter denoted by MR). In short, the team can be organized to follow a procedure which prescribes: how much information shops have to collect; how to identify ordinary/exceptional situations; and how to compute the new scale, if necessary.

Depending on the type of situation, we distinguish two different regimes: a coordination regime (in *exceptional* situations) and a routine regime (in *ordinary* situations). We propose two different procedures in order to provide an optimal level of information acquisition and team coordination based on a different definition of *exceptional* situations. In the first procedure (Proc I), situations are exceptional if at least one sales manager reports an alert message (i.e. she receives a signal that she classifies as exceptional); while in the second procedure (Proc II), since all shops' signals are collected together by the production unit, situations are exceptional if the combination of the signals produces an alert message, i.e. the evaluation of exceptionality is based on the composed signal.[1] The

[1] In the two-shop case, the difference between the two procedures occurs when one shop receives a positive signal from the market and the other receives a negative signal. In this occurrence, under Proc I, the team is in an exceptional situation, while under Proc II, the team is in an ordinary situation (since

likelihood that the coordination regime occurs provides a measure of team coordination.

The model also includes a production phase, which takes place after the scale choice and the demand realization. In this phase, each shop charges a price which optimally accounts for the scale choice. Therefore, when the situation is exceptional, there is team coordination for two reasons: first, the production unit chooses the scale based on the information of the shops; second, shops choose their prices (determining the total demand) based on the decision of the production unit.[2]

Since it has been recognized that new information and communication technologies (ICTs) are general purpose technologies, researchers have noted that the drastic fall recently registered in ICT costs has had an important impact on the design of a firm's information system, and, more generally, on the organization of the production (Bresnahan and Trajtenberg, 1995). In fact, ICTs have speeded up and favoured information acquisition and processing, and have proved to be useful to support decision-making implementation (Lauría and Duchessi, 2007). In modern manufacturing firms, for example, the use of ICTs makes it possible to rearrange production more simply, and productive processes more flexibly (Golden and Powell, 2000; Gong and Hu, 2007). To account for this, the results of this model will also be discussed in relation to the development of ICTs.

As expected, we find that the level of information acquisition and processing increases when acquisition costs and processing costs decrease and when environmental variability rises. Even if, in a strict sense, information acquisition and processing are not inputs of production, the rules governing their demand follow those of production factors: the lower costs or the larger (expected) returns imply a higher *input* demand. An empirical confirmation of this result can be found in Mendelson and Pillai (1998).

More interestingly, information acquisition and the level of team coordination turn out to be complementary, in the sense that increasing one makes the other more effective. Indeed, more precise signals make the team coordination more effective; furthermore, a higher level of team coordination increases the likelihood that a signal is processed, and hence the marginal return of gathering information increases, inducing more information acquisition. This result is in line with the Milgrom and Roberts (1990) hypothesis, and with the following empirical literature which has analyzed the link between ICT adoption (and usage) and the emergence of forms of horizontal coordination between firms, such as teams (Hitt and Brynjolfsson, 1997; Bresnahan et al., 2002).

Concerning this point and the observed trend involving increasing uncertainty and decreasing information and communication costs, we identify three phases of a firm's teamwork adoption: (1) permanent routine (no team); (2) team under Proc I; and, finally, (3) team under Proc II. This result emerges as Proc II performs better when information management costs are small, while Proc I becomes feasible for larger acquisition and processing costs. Therefore, an integrated information system (Proc II) may be profitable

the positive and the negative signals cancel each other out).

[2] Our model may have an alternative formulation, where the team is composed of many shops and one production unit, *at their service*. In this case, the scale decision is made up collectively by all the marketing managers, while the production unit plays no role. In the coordination regime, agents have to coordinate their actions in the sense that they have to share (combine) and process their information in order to make a decision.

only when the costs of processing information are sufficiently small. We also discuss some circular effects between ICT adoption and environmental variability.

Finally, we find that team size may affect the performance of the two procedures. The first one performs better when teams are small, while the second one is neutral to team size. That is, we expect that large teams are likely to be coordinated only for low information costs or when an efficient integrated information system is available.

Previous results are derived under the assumption that demand shocks are uncorrelated. A brief analysis of a more general set-up considering interdependent markets suggests that, because of complementarity, team coordination increases with signal correlation since firms have lower acquisition costs for obtaining the same amount of information. Moreover, we guess that, under high correlation and economies of scale in information acquisition and processing, a specialization of some shops in information acquisition tasks (test markets) may emerge.

The remainder of this paper is organized as follows. Section 2 introduces the main assumptions and develops a simple model that illustrates Proc I. In Section 3, we present Proc II as an alternative procedure. In Section 4, we compare the two procedures; we informally discuss the case of correlated signals, and we provide a brief discussion of the impact of ICTs on team coordination. Section 5 concludes.

1.1 Related literature

Our work combines the Bayesian approach to information acquisition with the theory of teams. The Bayesian approach to decision theory (Shavell, 1989; Bernardo and Smith, 1994) analyzes situations where agents have some prior beliefs on the states of nature and, after a *costly* experiment in light of this new information, update their beliefs. In general, the optimal level of information acquisition is determined by the maximization of the expected pay-off function. Agents would equate the marginal benefits of acquiring information to the additional costs of information. The recent literature has devoted new attention to information acquisition in different research fields. Persico (2000) has explored the consequences of the endogenous acquisition of information in auctions. Kim (1995) has studied the impact of information on the production and exchange of goods. Holmström (1979), Radner and Stiglitz (1984), and Maggi (1999) have clarified the role of information acquisition in the principal-agent relationship, in competitive environments, and under commitment.

The theory of teams (Marschak and Radner, 1972) starts from the observation that agents have limited computability skills, or limited time, and therefore they are 'boundedly rational' (Simon, 1955; Radner, 1996). The problem of conflicting objectives among agents is ignored, and the focus is instead on the problem of coordinating the decisions of several imperfectly informed actors and its effects on the performance of the firms.

In an MR version of 'management by exception' called 'report of exceptions' (MR, p. 206), each agent can directly make a decision about her action variable or choose to *pass the buck* to a central agency. It is supposed that, when observation is ordinary, the agent makes a decision just based on her observation, while in the case in which the observation is exceptional she reports to the central agency, which then decides in her place, taking into account her report of exceptions and those of other agents incurred in exceptional observations. In a second version, called ‘emergency call’ (MR, p. 217), the coordinated decision is obtained by all managers on the stimulus of at least one agent who has received an exceptional signal. Our set-up lies in between, since the production unit acts as a central agency, but the coordination decision is based on all pieces of information and not only on those that are exceptional.

Our paper differs from the MR set-up in many respects and is much closer to the Carter (1995) model.[3] Nevertheless, a comparison between their findings and ours is not without interest. First, MR show that the pay-off (gross of information management costs) increases with the coordination level, although at a decreasing rate. Second, provided that processing costs are a positive function of the frequency of exceptions, it follows that the optimal level of coordination negatively depends on processing costs. Both results are confirmed in our set-up. Finally, MR show that the gross pay-off increases more than proportionally with the size of the team. This result coincides with ours under Proc I, but not under Proc II where the average gross pay-off is size-free.

Carter (1995) models a situation where two agents (i.e. the marketing department and the production department) observing noisy signals are involved in the choice of a common variable. Agents use fixed acquisition devices and have noisy communication channels. In Carter’s paper, the steps necessary to reach a decision vary according to the choice of the organizational structure. For example, in the ‘production-led firm’, Carter assumes that the marketing department condenses its information in a report that it sends to the production department which receives it with some added noise. The production department combines the two pieces of information and makes a decision. In the ‘routine firm’, no information at all is communicated and the decision is predetermined. Our model swings between these two extreme cases: in the routine regime, agents behave as a ‘routine firm’, and in the coordination regime they behave as a ‘production-led firm’.

Crémer (1980) shows that, when organizations are too complex to be managed unitarily, the design of an organization consists of choosing that configuration that minimizes market uncertainty. Sah and Stiglitz (1986) and Aoki (1986) discuss the level of centralization in an organization. Geanakoplos and Milgrom (1991) analyze the case in which managers can have heterogeneous abilities for information gathering and show that abler managers should be assigned to higher levels.

Radner (1993) proposes a model of parallel processing in which information is spread around the organization and takes time to be elaborated. His work, and the following contributions, all focus on finding the hierarchical structures within which information is processed to reach the maximum pay-off. Radner (1993) describes those hierarchical structures within which information is processed at maximum speed. In Van Zandt and Radner (2001), the optimal hierarchical structure takes into account speed and quality of decision. Schulte and Grüner (2007) analyze a similar set-up where agents may make mistakes. Van Zandt (1998) investigates the properties of the organization when they are not necessarily hierarchical. In his set-up, processing costs depend on the number of

[3] The main differences with the MR assumptions are as follows: (i) we have assumed a common decision variable; (ii) agents acquire noisy signals so that in the pooling case there is not complete information; (iii) information acquisition is endogenous; and (iv) we explicitly account for information and processing costs.

managers necessary to process the information and on the cost of delay.

Previous contributions also relate the size of the organizations to the processing costs. Radner (1993) provides the conditions under which there are scale economies in processing information. Van Zandt and Radner (2001) analyze the case where there are diseconomies of scale. In our model, processing costs are proportional to the size of the team for each coordination level. This means that we find (dis)economies of scale in processing information when coordination reduces (increases) with the size of the team.

2 The model

Notation. The notation used in this paper is standard. Scalar quantities are in normal letters (e.g. X_1, X_2, ..), and vectors are in bold (e.g. $\mathbf{X}$, $\mathbf{Y}$, $\mathbf{1}$, ..). $\mathbf{XY} := \langle \mathbf{X}, \mathbf{Y} \rangle$ indicates the scalar product. $\mathbf{1}$ is an array in which each entry is a 1. $\times$ is the Cartesian product of two sets. We denote g_X the density distribution of the random variable X; and E and Var are the expected value and the variance operators, respectively. $E_{X \in W}(\cdot) = E(\cdot | X \in W)$, and $Var_{X \in W}(\cdot) = Var(\cdot | X \in W)$ are the expected value and variance conditional on $X \in W$.

The team. There are $n + 1 \geq 2$ agents, called a_0, a_1, .., a_n, who compose a team (firm). Agent a_0 is the production manager, and agent a_i, $i \in \{1, .., n\}$, is the sales manager for market i. All the agents work for the interest of the firm, so that the problem of conflicting objectives among agents is ignored.

The demand. The demand in market i is uncertain, and it is given by:

$$y_i = 4bV_i p_i^{-2}, \tag{1}$$

where $b > 0$ is a parameter; y_i is the quantity demanded; p_i is the price charged in the market; and V_i is a random variable describing the states of nature. V_i is normally distributed with mean $\bar{v}_i$ and variance β_i. We call g_{V_i} the prior density distribution of V_i, and we assume that V_i and V_j, with $i \neq j$, are independent.

Production. Production technology is summarized by the following cost function:

$$C(q, y) = \frac{1}{2}aq^2 + y/q + d, \tag{2}$$

where $a, d > 0$ are constants; $y = \sum_{i=1}^{n} y_i$ is the production level; and q is a technology parameter positively affecting the optimal scale (hereafter, scale). The marginal cost of production, $1/q$, reduces with the increase of q, a quasi-fixed input of the production process (capital), which costs: $aq^2/2$ (see, for example, Mialon, 2008).

Before putting goods up for sale and before knowing the demand level, the production unit has to decide on the production scale q. Afterwards, when demand realizes, the optimal quantity (i.e. the quantity that maximizes the pay-off) is produced and sold by the shops. Hence, there is output flexibility in the production phase, but production costs are affected by the decision on scale, that in turn is affected by the choice of a quasi-fixed input.

Gross pay-offs. Using equations (1) and (2), and assuming profit maximizing behaviour of firm, we obtain the following (reduced form) gross pay-off function, that is quadratic in the scale choice and linear in the unknown (Carter, 1995):[4]

$$U(q, \mathbf{V}, n) = -\frac{1}{2}aq^2 + b\left(\textstyle\sum_{i=1}^{n} V_i\right)q - d. \tag{3}$$

From now on, we do not explicitly model the production phase, and we focus on the decision process concerning the choice of q.

Information management. Agents can manage information at a cost: sales managers can acquire information on the market conditions, and the production manager has the ability to process this information. Since demand is uncertain, shops can not observe the true state of nature $\mathbf{v} = (v_1, v_2, .., v_n)$, but they can acquire a signal $\mathbf{X}^{\boldsymbol{\lambda}} = \left(X_1^{\lambda_1}, X_2^{\lambda_2}, .., , X_n^{\lambda_n}\right)$, correlated with the demand. In particular, we assume that agent a_i can collect a noisy signal $X_i^{\lambda_i}$ that is normally distributed with mean $\bar{v}_i$ and variance β_i/λ_i, where $\lambda_i \in [0,1]$ is a measure of the (relative) precision of the signal. Each signal is correlated to the corresponding state of nature but they are pairwise independent. The conditional distribution of the signal $X_i^{\lambda_i}|V_i = v_i$ is normally distributed with mean v_i and variance $\beta_i(1-\lambda_i)/\lambda_i$. Shops update their information using the Bayesian rule, and therefore the posterior distribution is given by the random variable $V_i|X_i^{\lambda_i} = x_i$ that is normally distributed with mean $\lambda_i x_i + (1-\lambda_i)\bar{v}_i$ and variance $\beta_i(1-\lambda_i)$. We assume that the cost of the signal acquisition for each shop is: $K(\cdot) = k\bar{K}(\cdot)$, where k is a measure of the information acquisition costs, and $\bar{K} : [0,1] \to \Re_+$ is a function of the (relative) precision of the signal, with $\bar{K}(0) = 0$, $\bar{K}', \bar{K}'' > 0$, and $\bar{K}'(1) = \infty$.[5] The production unit can combine different pieces of information collected by shops and analyze them to make a decision. Let c be the cost of processing the information coming from one shop. In Proc II (see Section 3), we split the information processing into two separate phases: in the first phase, each piece of information is combined at a cost, φc, with $\varphi \in [0,1]$, and, in the second phase, it is analyzed at costs $(1-\varphi)c$.

Finally, we assume that shops can make an individual assessment (i.e. they are able to say whether their market condition is exceptional or ordinary) as a by-product of information acquisition, and that the production unit can make an assessment on the joint information after combining previous information.

[4] Equating marginal revenues and marginal costs in each market i, we obtain: $MR_i = (4bV_i/y_i)^{1/2} = q^{-1} = MC_i$; therefore the optimal prices and quantities are, respectively: $p_i = 2/q$ and $y_i = bV_i q^2$. After replacing y_i in the profit function, the overall profits are given in (3).

[5] For example, consider the case where $X_i^{\lambda_i}$ is a random variable describing the sample average of h independent and identically distributed experiments analysing V_i, each giving as the result $X_{i,l} = V_i + e_{i,l}$, where $e_{i,l}$ is a normal random variable with mean 0 and variance $\beta\hat{\varepsilon}$. Hence, $X_i^{\lambda_i(h)} = \frac{1}{h}\sum_l X_{i,l} = V_i + e_i^h$, where e_i^h is a normal random variable with mean 0 and variance $\beta_i\hat{\varepsilon}/\sqrt{h}$, and $\lambda_i = L_i(h) = 1/\left(1 + Var(\varepsilon_i^h)\right) = 1/\left(1 + \hat{\varepsilon}/\sqrt{h}\right) = \frac{\sqrt{h}}{\hat{\varepsilon}+\sqrt{h}}$. If k is the cost of each experiment, then the cost of obtaining a signal with precision λ_i is: $K(\lambda_i) = kL_i^{-1}(\lambda_i) = k\frac{\lambda_i^2\hat{\varepsilon}}{(1-\lambda_i)^2}$. On the other hand, if there are economies of scale in collecting data, so that acquisition costs increase with the square root of h, then: $K(\lambda_i) = k\sqrt{L_i^{-1}(\lambda_i)} = k\frac{\lambda_i\sqrt{\hat{\varepsilon}}}{1-\lambda_i}$.

Procedures. The teamwork is governed by a procedure that is a sequence of (simple) instructions and choice rules (contingent instructions) that organize and coordinate the agents' tasks. In this paper we analyze a simple procedure that is usually referred to as 'management by exception'. This procedure distinguishes two different regimes, depending on the signals received by the agents: a routine regime, when each signal x_i is in a routine interval R_i, i.e. $x_i \in R_i \subset \Re$ for $i = 1, .., n$ or $\mathbf{x} \in \mathbf{R}$, where $\mathbf{x} = (x_1, .., x_n)$ and $\mathbf{R} = \times_{i=1..n} R_i$; and a coordination regime, when at least one signal is out of the routine interval, i.e. $\mathbf{x} \in \bar{\mathbf{R}} = \Re^n \backslash \mathbf{R}$. We define the coordination level O as the probability that the coordination regime occurs, i.e. $O = 1 - P_{\mathbf{R}} = P_{\bar{\mathbf{R}}} = \Pr\left(\mathbf{X} \in \bar{\mathbf{R}}\right)$.

The procedure includes the following tasks involving the sales agents and the production agent. Each sales agent acquires a signal $X_i^{\lambda_i}$ correlated with the demand in her market and returns an alert message to the production unit if the event is exceptional, i.e. $x_i \notin R_i$. The production manager, if he observes, at least, one alert message, informs the sales managers that they are in the coordination regime and asks them to send him the information they have collected. He combines together different pieces of information collected by shops, analyzes them and makes a decision on the production scale. Otherwise, i.e. in the routine regime, he chooses a predetermined scale without asking the sales managers for any piece of information.

Net pay-offs. We denote u as the net pay-off that is obtained from (3) by subtracting the costs of acquiring and processing the information:

$$u(q, \mathbf{V}, \boldsymbol{\lambda}, n) = U(q, \mathbf{V}, n) - \textstyle\sum_{i=1}^{n} K(\lambda_i) - nc\mathcal{I}, \tag{4}$$

where $\mathcal{I} = 0$ when the team enters the routine regime, and $\mathcal{I} = 1$ when the team enters the coordination regime. Since $\mathbf{V}$ is unknown, collecting and processing information is useful in order to choose an adequate scale q. However, since managing information is costly, shops must acquire too detailed information, and, in some occurrences (ordinary situations), the production manager must decide not to process it.

Finding an optimal procedure implies identifying the optimal quality of the signal acquisition $\boldsymbol{\lambda}$, the optimal routine region $\mathbf{R}$, and the optimal scale q.

Before characterizing the optimal procedure Proc I, we show that the optimal routine area is rectangular and is centred around the average value of the signal.

Proposition 1 *The (almost everywhere) unique optimal routine area is given by* $\mathbf{R} = \times_i R_i$*, where* $R_i = [\bar{v}_i - r_i, \bar{v}_i + r_i]$ *, and the optimal routine scale is given by:* $q_R = \frac{a}{b}\mathbf{1}\bar{\mathbf{v}}$*.*

Proof The proof is done by choosing an arbitrary level of coordination O, and of signal quality $\boldsymbol{\lambda}$. Without loss of generality, we assume that $a = b = 1$, $\bar{v}_i = d = 0$, since the general result can be obtained by an appropriate change of unit of q and $\mathbf{V}$. After previous simplifications, (3) becomes $U(q, \mathbf{V}, n) = -\frac{1}{2}q^2 + q(\mathbf{1V})$. We allow $\mathbf{R}$ to be any possible set generated by the Cartesian product of Borelian sets, i.e. $\mathbf{R} = \times_{i=1..n} R_i$, where $R_i = \cup_h^\infty S_h$, and where $S_h = [r_h, s_h]$ with $r_h, s_h \in \Re$, such that $\Pr(\mathbf{X} \in \mathbf{R}) = 1 - O$.

From the first-order condition, the optimal routine scale for the routine region $\mathbf{R}$ is: $q_R = E_{\mathbf{X} \in \mathbf{R}}(\mathbf{1V}) = E_{\mathbf{X} \in \mathbf{R}}(\boldsymbol{\lambda}\mathbf{X})$, and the optimal coordination scale receiving signal $\mathbf{X}$ is

$q^*(\mathbf{X}) = E_{\mathbf{V}|\mathbf{X}}(\mathbf{1V}) = \boldsymbol{\lambda}\mathbf{X}$. Let L_R be the expected loss by choosing q_R and not $q^*(\mathbf{X})$:

$$\begin{aligned} L_R &= E_{\mathbf{X}\in\mathbf{R}} E_{\mathbf{V}|\mathbf{X}} U(q^*(\mathbf{X})) - E_{\mathbf{X}\in\mathbf{R}} E_{\mathbf{V}|\mathbf{X}} U(q_R) \\ &= E_{\mathbf{X}\in\mathbf{R}}\left(-(\boldsymbol{\lambda}\mathbf{X})^2/2 + E_{\mathbf{V}|\mathbf{X}}(\mathbf{1V})(\boldsymbol{\lambda}\mathbf{X})\right) - E_{\mathbf{X}\in\mathbf{R}}\left(-q_R^2/2 + (\boldsymbol{\lambda}\mathbf{X}) E_{\mathbf{V}|\mathbf{X}}(q_R)\right) \\ &= E_{\mathbf{X}\in\mathbf{R}}(\boldsymbol{\lambda}\mathbf{X})^2/2 - E^2_{\mathbf{X}\in\mathbf{R}}(\boldsymbol{\lambda}\mathbf{X})/2 \\ &= Var_{\mathbf{X}\in\mathbf{R}}(\boldsymbol{\lambda}\mathbf{X})/2 \end{aligned} \tag{5}$$

Hence, the problem is choosing $\mathbf{R}$ so that the loss is minimized, while simultaneously providing the level of coordination O:

$$\min_{\mathbf{R}} L_{\mathbf{R}} = Var_{\mathbf{X}\in\mathbf{R}}(\boldsymbol{\lambda}\mathbf{X})/2, \quad \text{subject to} \quad \Pr(\mathbf{X}\in\mathbf{R}) = 1 - O. \tag{6}$$

Note that $Var_{\mathbf{X}\in\mathbf{R}}(\boldsymbol{\lambda}\mathbf{X}) = \sum_{i=1}^n \lambda_i^2 Var_{X_i\in R_i}(X_i)$ and, from independence, $\Pr(\mathbf{X}\in\mathbf{R}) = \prod_{i=1}^n \Pr(X_i \in R_i)$. This means that once $\mathbf{R}_{-i} = R_1 \times .. \times R_{i-1} \times R_{i+1} \times .. \times R_n$ is chosen optimally, the choice of R_i is given by the solution of this unidimensional problem: $\min_{R_i} L_{R_i} = \int_{R_i} \left(x_i - \mu_{R_i}\right)^2 \phi_{\beta_i/\lambda_i}(x_i)\,dx_i$, where $\mu_{R_i} = \int_{R_i} x_i \phi_{\beta/\lambda}(x_i)\,dx_i$, subject to $\int_{R_i} \phi_{\beta_i/\lambda_i}(x_i)\,dx_i = \Pr(\mathbf{X}\in\mathbf{R}) / \Pr(\mathbf{X}_{-i}\in\mathbf{R}_{-i})$, where ϕ_{β_i/λ_i} is the density of a normal distribution with mean 0 and variance β_i/λ_i, and $\mathbf{X}_{-i} = X_1 \times .. \times X_{i-1} \times X_{i+1} \times .. \times X_n$. First note that, for any given μ_{R_i}, the minimum is reached when R_i is almost everywhere a closed interval. In fact, for all the possible R_i, moving mass from the tails of the distribution towards the centre consists in a variance reduction. Now, since X_i has a centred normal distribution, of all the closed intervals, the one with minimum variance is that centred in 0. ■

Intuitively, since choosing a pre-determined scale q_R generates a reduction in the gross pay-off with respect to choosing the optimal scale based on the signal, $q^*(\mathbf{X})$, and the loss increases quadratically with the distance between q_R and q^*, then, in order to minimize the average loss, the optimal routine scale must be the more likely value, and the optimal region must be the closest area to the optimal routine scale.

For a given routine region $\mathbf{R}$ and signals precision $\boldsymbol{\lambda}$, the net expected pay-off is:

$$\begin{aligned} \hat{u}_I(\boldsymbol{\lambda}, \mathbf{R}, n) &= EU(q^*(\mathbf{X}), \mathbf{V}, n) - P_{\mathbf{R}} \cdot L_{\mathbf{R}} - d - \textstyle\sum_{i=1}^n K(\lambda_i) - nc(1 - P_{\mathbf{R}}) \\ &= \frac{b^2}{2a}\left[Var(\boldsymbol{\lambda}\mathbf{X}) + (\mathbf{1}\bar{\mathbf{v}})^n - P_{\mathbf{R}} Var_{\mathbf{X}\in\mathbf{R}}(\boldsymbol{\lambda}\mathbf{X})\right] - d \\ &\quad - \textstyle\sum_{i=1}^n K(\lambda_i) - nc(1 - P_{\mathbf{R}}). \end{aligned}$$

The term in square brackets is the difference between the gross expected pay-off that the team receives if the scale is optimally adjusted in both regimes and the loss of choosing a predetermined scale in the routine regime given in (5) times the probability it occurs. The last two terms are the information management costs.

We will rewrite the pay-off function in a suitable way considering the different terms. First, $Var(\boldsymbol{\lambda}\mathbf{X}) = \sum_i \beta_i \lambda_i$. Second,

$$P_{R_i} = \Pr\left(X_i^{\lambda_i} - \bar{v}_i \in [-r_i, r_i]\right) = \int_{\bar{v}_i - r_i}^{\bar{v}_i + r_i} g_{X_i^{\lambda_i}}(x)\,dx = \int_{-A_i}^{A_i} \phi(z)\,dz, \tag{7}$$

where $\phi(\cdot)$ is the normal standard density. The last equivalence of (7) follows by the changes of variable $z = (x_i - \bar{v}_i)\sqrt{\lambda_i/\beta_i}$ and $A_i = r_i\sqrt{\lambda_i/\beta_i}$. Let $F(A_i) := \int_{-A_i}^{A_i} \phi(z)\,dz = P_{R_i}$.

Finally,

$$\begin{aligned}
P_{\mathbf{R}} Var_{\mathbf{X}\in\mathbf{R}}(\boldsymbol{\lambda}\mathbf{X}) &= \int_{\bar{v}_1-r_1}^{\bar{v}_1+r_1} .. \int_{\bar{v}_n-r_n}^{\bar{v}_n+r_n} \left[\textstyle\sum_i \lambda_i (x_i - \bar{v}_i)\right]^2 g_{\mathbf{X}^{\lambda}}(\mathbf{x})\,d\mathbf{x} \\
&= \textstyle\sum_i \mathbf{R}_{-i} \displaystyle\int_{\bar{v}_i-r_i}^{\bar{v}_i+r_i} \left[\lambda_i (x_i - \bar{v}_i)\right]^2 g_{X_i^{\lambda_i}}(x_i)\,dx_i \\
&= \textstyle\sum_i P_{\mathbf{R}_{-i}} \beta_i \lambda_i \displaystyle\int_{-A_i}^{A_i} z_i^2 \phi(z_i)\,dz_i \\
&= \textstyle\sum_i \beta_i \lambda_i \left[\prod_{j\neq i} F(A_j)\right] \left[F(A_i) - A_i F'(A_i)\right],
\end{aligned}$$

where the second line follows by independence, the third line by a change of variable, and the last line by integration by parts.

Summing up these results yields:

$$\begin{aligned}
\hat{u}_I(\boldsymbol{\lambda}, \mathbf{A}, n) &= \frac{b^2}{2a} \textstyle\sum_i \beta_i \lambda_i \left\{1 - \left[\prod_{j\neq i} F(A_j)\right] \left[F(A_i) - A_i F'(A_i)\right] + (\mathbf{1}\bar{\mathbf{v}})^2\right\} \\
&\quad - \textstyle\sum_i K(\lambda_i) - nc\left(1 - \prod_i F(A_i)\right).
\end{aligned} \tag{8}$$

We now focus on the symmetric case and we introduce some normalizations: $\beta_i = \beta$, $\lambda_i = \lambda$, $\bar{v}_i = \bar{v}$, $A_i = A$, $r_i = r$ with $i = 1,..,n$, and $\frac{b^2}{2a} = 1$,$(\mathbf{1}\bar{\mathbf{v}})^2 = d$. Previous considerations simplify equation (8) in the following way:

$$\begin{aligned}
\hat{u}_I(\boldsymbol{\lambda}, \mathbf{A}, n) &= n\beta\lambda \left\{1 - F(A)^{n-1}\left[F(A) - AF'(A)\right]\right\} \\
&\quad -nK(\lambda) - nc\left(1 - F(A)^n\right),
\end{aligned} \tag{9}$$

where $A = r\sqrt{\lambda/\beta}$.

Figure 1 depicts the level of organization $O = 1 - P_{\mathbf{R}} = 1 - F(A)^n$ and the quality of signal acquisition λ that maximize the net pay-off under Proc I for different values of c, k and β, when $K(\lambda) = k\lambda/(1-\lambda)$. As we expected, changes in acquisition costs principally affect information acquisition, while changes in processing costs modify the level of coordination. An increase in the environmental variability affects both dimensions significantly.

[Figure 1 around here]

We focus on the quantity $\hat{u}_I(\lambda, A, n)/n$, that is the expected pay-off per shop. The following proposition proves that $\hat{u}_I/n$ is decreasing in n, and that there are situations where small teams are profitable but not large teams.

Proposition 2 *Assume that n is a continuous variable in the domain $[1,\infty)$. Denote $u_I^*(\lambda^*, A^*, n)/n$ as the expected pay-off per agents choosing $\lambda^*(n)$ and $A^*(n)$ optimally. Then:*

1. $\frac{d}{dn}\left[u_I^*\left(\lambda^*, A^*, n\right)/n\right] < 0$*, and*

2. for every n*,* n'*, with* $n < n'$*, there exists a pair* (c, k) *such that* $u_I^*\left(\lambda^*, A^*, n\right)/n > 0$ *and* $u_I^*\left(\lambda^*, A^*, n'\right)/n' \leq 0$*.*

Proof 1.) By the envelope theorem, $\frac{d}{dn}\left[u_I^*/n\right] = \frac{\partial}{\partial n}\left[u_I^*/n\right] = -\beta\lambda F^{n-1}\ln F\left(F - AF'\right) + cF^n \ln F$. Since $F < 1$, then $\ln F < 0$. The sign of the derivative is the sign of the following expression $\beta\lambda\left(1 - A\frac{F'}{F}\right) - c$. From the first-order condition for equation (8), we have $\beta\lambda\left(\frac{n-1}{n}\left(1 - A\frac{F'}{F}\right) + \frac{A^2}{n}\right) - c = 0$, and hence $\frac{d}{dn}\left[u_I^*/n\right] \geq 0$ if and only if $\left(\frac{n-1}{n}\left(1 - A\frac{F'}{F}\right) + \frac{A^2}{n}\right) \leq \left(1 - A\frac{F'}{F}\right)$ or $\frac{1}{n}\left(1 - A\frac{F'}{F} - A^2\right) \geq 0$, which is impossible.

2.) From point 1 and by continuity of the pay-off function with respect to c and k, we reach the thesis. ■

[Figure 2 around here]

In Figure 2 we show the maximum number of agents for different values of the communication costs and processing costs for $n = 1, 2, 3$ and ∞. Points below the line correspond to pair (c, k) where teamwork is profitable. The feasible region decreases with n.

In addition, taking the limit with $n \to \infty$, we note that $F\left(A\right)^n \to 0$ if $A < \infty$, and $F\left(A\right)^n \to 1$ when $A = \infty$. Hence, with an infinity of agents, there are only two extreme regimes: routine or full coordination. Since $\left[F\left(A\right) - AF'\left(A\right)\right]$ is bounded, it emerges that:

$$\lim_{n\to\infty}\frac{\hat{u}_I}{n} = \begin{cases} \beta\lambda - K\left(\lambda\right) - c & \text{if } A^* < \infty \\ 0 & \text{if } A^* = \infty \end{cases}.$$

Hence, there is full coordination with $K'\left(\lambda^*\right) = \beta$ if $\beta\lambda^* \geq K\left(\lambda^*\right) + c$ and routine if $\beta\lambda^* < K\left(\lambda^*\right) + c$. The following proposition resumes the result.

Proposition 3 *Assume that* $n \to \infty$*. Then there are only two possible cases: no coordiantion or full coordination.*

Proof In the text. ■

Intuitively, when the number of agents increases, the likelihood that at least one observes an exceptional signal becomes very high, unless alert threshold A^* is expanded. When $n \to \infty$ the only way not to have an exceptional situation is to choose $A^* = \infty$, i.e. asking shops never to signal an alert message. Proposition 3 suggests that this procedure is not particularly suitable when n is large.

3 An alternative procedure

In this section, we present Proc II, an alternative procedure which differs from the previous one in the computation of exceptional situations. This implies a different partition of the signal space in routine and cooperative regimes, and different costs for information processing. Proc II includes the following tasks involving the sales agents and the production agent. Each sales agent acquires a signal $X_i^{\lambda_i}$ correlated with the demand in her market whose cost is $K(\lambda)$, and afterwards she transfers her information (whatever it is) to the production unit, which combines it with all the shops' signals thus obtaining a joint signal $X_C = \mathbf{1X}^{\boldsymbol{\lambda}}$ at the cost $n\varphi c$. After this phase, the production unit is able to make an assessment of the overall demand (i.e. whether the situation is exceptional or ordinary). When the production manager recognizes an exceptional situation he informs the sales managers that the team is in the coordination regime and he makes a decision on the production scale at the cost $n(1-\varphi)c$. Otherwise, i.e. in the routine regime, he chooses a predetermined scale.[6]

The gross pay-off of the team is provided by (3), and the net pay-off, previously provided by (4) modifies in the following way:

$$u(q, \mathbf{V}, \boldsymbol{\lambda}, n) = U(q, \mathbf{V}, n) - \textstyle\sum_i K(\lambda_i) - n\varphi c - n(1-\varphi)c\mathcal{I}, \tag{10}$$

where $\mathcal{I} = 0$ when the team enters the routine regime, and $\mathcal{I} = 1$ when the team enters the coordination regime.

The following proposition is the analogue of Proposition 1, when the production manager has put together the shops' signals before deciding on the regime.

Proposition 4 *The (almost everywhere) unique optimal routine area for the joint signal* $X_C = \mathbf{1X}^{\boldsymbol{\lambda}}$ *is given by* R*, where* $R = [\mathbf{1\bar{v}} - r, \mathbf{1\bar{v}} + r]$ *, where* $r > 0$*, and the optimal routine scale is given by:* $q_R = \frac{a}{b}\mathbf{1\bar{v}}$*.*

Proof The proof is similar to that of Proposition 1 assuming $n = 1$, $X_1 = X_C$, and $V_1 = \mathbf{1V}$. ■

Comparing Propositions (1) and (4), it emerges that the signal space is partitioned differently in the two procedures. In the two-shop case, under Proc I, the routine region is a square ($\mathbf{R}_I = \{\mathbf{x} | \; |x_1| \leq r, |x_2| \leq r\}$); while under Proc II, it is a strip centred on the bisectrix of the second and fourth quadrant ($\mathbf{R}_{II} = \{\mathbf{x} | \; |x_1 + x_2| \leq r\}$). Similar computations apply to obtain the net pay-off function of Proc II:

$$\begin{aligned} \hat{u}_{II}(\boldsymbol{\lambda}, \mathbf{A}, n, \varphi) &= n\beta\lambda\left[1 - F(A) + AF'(A)\right] \\ &\quad -nK(\lambda) - n\varphi c - n(1-\varphi)c(1 - F(A)), \end{aligned} \tag{11}$$

where $A = r\sqrt{\lambda/\beta}$.

Equation (11) shows that the expected pay-off per agent $\hat{u}_{II}(\boldsymbol{\lambda}, \mathbf{A}, n, \varphi)/n$ is not affected by the size of the team. Hence, provided that there is a profitable technology for collecting information together in a team composed of two agents, then it also permits teams composed of $n > 2$ agents. Simulations confirm the results obtained under Proc I.

The following proposition is the analogue of Proposition 2.

Proposition 5 *Denote* $u^*_{II}(\lambda^*, A^*, n)/n$ *as the expected pay-off per agents choosing* λ^* *and* A^* *optimally, then:*

[6] Without explicitly considering the production phase, the role of the sale managers is limited to gathering a signal, so that this procedures seem quite centralized. The need to inform the sales managers is because they have to modify their shop prices since q will be changed.

1. *for every n, $\frac{d}{d\varphi}\left[u^*_{II}(\lambda^*, A^*, \varphi)/n\right] < 0$ and*

2. *for every n and for every $\varphi, \tilde{\varphi} \in (0,1)$ with $\varphi < \tilde{\varphi}$, there exists a pair (c,k) such that $u^*_{II}(\lambda^*, A^*, \varphi)/n > 0$ and $u^*_{II}(\lambda^*, A^*, \tilde{\varphi})/n \leq 0$.*

Proof Similar to the Proof of Proposition 2. ■

[Figure 3 around here]

In Figure 3, we show the thresholds for which teamwork is feasible under Proc II, for $\varphi = 0$, 0.25, 0.5 and 1. Points below the line correspond to pair (c,k) where coordination is profitable. The feasible region decreases with φ.

4 Discussion

In this section we will focus on four issues. Firstly, we investigate when Proc I is equivalent to Proc II. Secondly, we compare the relative performance of the two procedures. Thirdly, we briefly discuss the case when demand shocks (and hence signals) are correlated. Finally, we provide a brief description of the impact of ICTs on team coordination.

We denote $u^*_I(c,k,n)$ as the maximal pay-off when a team follows Proc I. Analogously, we denote $u^*_{II}(c,k,\varphi)$ the maximal pay-off under Proc II. We start by describing two equivalence results.

Proposition 6 *For every c and k, Proc I and Proc II are equivalent, i.e. $u^*_I(c,k,n) = u^*_{II}(c,k,\varphi)$, when:*

A $n = 1$ and $\varphi = 0$, and

B $n = \infty$ and $\varphi = 1$.

Proof Straightforward. ■

From Proposition 6.A, the profit when there is a single shop under Proc I and the profit when the production unit has no costs in combining information under Proc II are the same. Similarly, from Proposition 6.B, an infinite number of firms under Proc I or no costs in processing information under Proc II lead a team to gain the same pay-offs. In these limiting situations, the pay-off equivalence emerges as the partition of the signal space (i.e. the routine and cooperation areas) coincides in the two procedures: in A, the routine region is an identical interval for both procedures; in B, there is no routine regime, since information is always combined and processed under Proc II, and thanks to Proposition 3 under Proc I.

From Propositions 2 and 5, we also know that Proposition 6 indicates the upper and the lower bounds of the pay-off function for any combination of c and k. More precisely, for any c and k, the net pay-off is maximal in case A, i.e. $u^*_I(c,k,1) = u^*_{II}(c,k,0) = u_{\mathrm{A}}(c,k)$, and minimal in case B, i.e. $u^*_I(c,k,\infty) = u^*_{II}(c,k,1) = u_{\mathrm{B}}(c,k)$. Even if the two procedures have the same limiting bounds, the interpretation of the conditions under which these outcomes are reached is quite different. Under Proc I, the maximal pay-off can be only reached at the expense of reducing the team to a single shop, while under Proc II, it occurs thanks to an inexpensive combining technology. On the other hand, Proc I leads to the minimal pay-off when the number of agents is infinite, while under Proc II, we obtain this result when the production unit can not gather information together without processing it.

In Figures 4, 5 and 6, we compare Proc I with Proc II for different parameter values. When the processing and acquisition costs are sufficiently low, it emerges that Proc II is always better than Proc I. Comparing Figures 4 and 5, we notice that Proc I is more effective than Proc II when n is small. The efficiency of Proc I drastically reduces when the number of agents increases. Similarly, comparing Figures 4 and 6, we notice that Proc II is more effective than Proc I when φ is small. Finally, when costs of combining information are low, Proc II is preferred to Proc I, but, when they are high, the set of points where Proc II dominates Proc I is small.

[Figures 4, 5 and 6 around here]

In this paper, the analysis was developed by considering independent markets. In the presence of demand shock correlations (and correlated signals), the performance of the above procedures change. For example, if the production unit recognizes that there are positive correlations between shocks, it can improve the estimation of the demand for a market by combining the signal coming from that market with those of others. This has contrasting effects. First, since the marginal contribution of a signal is larger than in the case of independency, information acquisition is stimulated. Second, since the precision of the estimates of market demand is increased by using other signals, each shop can reduce its signal acquisition. The relative magnitude of these two effects clearly depends on the degree of correlation between signals and on the structure of signal acquisition costs. However, even if the second effect dominates the first one, we expect that the precision of the composed signal will increase, and, because of complementarity, the coordination (see: Figure 1). Note that positive correlation of demand may have an additional impact on information acquisition and coordination, since it implies a larger variability of the overall demand $\sum_{i=1}^{n} V_i$. In this case, we also expect more precision in the estimation of the demand and more coordination.

Market interdependence may also have a *qualitative* impact on the procedure design. In fact, to reduce processing and acquisition costs, a team can decide to make some shops specialized in information acquisition and use this information to provide an overall valuation of market conditions. This policy has increasing advantages when there are scale economies in gathering information and/or in the information processing. In an n-shop case, with sufficiently highly correlated demands, one of the previous conditions is sufficient to induce the team to choose to make only one shop specialized in information acquisition. In practice, the use of test markets is widely employed in marketing for the launch of new products, as well as in monitoring the evolution of a market (Gerald and Baron, 1977).

Organizational design can be analyzed together with the development of ICTs. In particular, we propose an explanation of the positive association of the team organizational form, high levels of ICT adoption, and high labour quality, as found by Bresnahan et al. (2002).

There are two key aspects, which characterize the design of modern firms. First, teams are forms that are useful to manage complex and uncertain situations. Complexity requires that team members are specialized, and uncertainty requires that firms react promptly to changes. Second, ICTs are tools that boost the management of information. More specifically, we assume that improvements in ICTs are reflected in a reduction of the costs of information acquisition and processing, i.e. c and k.[7]

Figure 4 sketches a path of organizational change when firms face complex and uncertain situations and information management costs decrease over time. We start at a point of time (time 0), when there are some activities in the firm that, because of their complexity, require the contribution of complementary skilled workers. If the costs of acquiring and processing information are high, these activities are organized in a permanent routine regime (and teams are not formed), but if these costs become lower (e.g. thanks to an improvement in ICTs), the team organizational form emerges. For large values of c and k (time 1 to 2), Proc I is the only available technology. Afterwards (between time 2 and 3), the team can be also organized using Proc II, although Proc I is still more profitable. Finally (at time 3), Proc II becomes the best procedure.

Our interpretation does not substantially differ from that of the Bresnahan et al. (2002) paper, even if there is a different emphasis. We assume that a firm engages in team practices when an activity requires the contribution of skilled workers, and the low costs of information managing make team functioning feasible. Bresnahan et al. explain their empirical findings by assuming complementarities between the team organizational form, ICT tools, and specialized workers. It is worth noting that our framework also implies that ICT technologies are complementary (see: Figure 1). In fact, as a consequence of a decrease in the processing costs, the team increases the level of coordination. Hence, the contribution of the collected information increases, and consequently there is also an increase in the demand for information acquisition technologies. Conversely, if there is a reduction of acquisition costs, by the law of demand, the team improves its acquisition technologies. Thus, information can be more profitably processed, and hence the demand for the processing technologies also increases.

Environmental uncertainty plays an important role in team formation. When the uncertainty is low, the gains for coordination difficulty outweigh the costs of the information system. Therefore, we expect that the likelihood of forming a team is low. Conversely, when uncertainty is high, there is scope to make profits with teamwork.

The outcomes of the model suggest some circular effects between ICT adoption and environmental variability that should be investigated in a more general framework. In our set-up, a reduction in ICT costs, *ceteris paribus*, induces larger variability in the decision

[7] Interestingly, Nault (1998) in order to analyze the impact of ICTs on the organization design and location decision investment, imposes that the adoption of ICTs (e.g. "decision support systems, group decision support systems, executive information systems and expert systems", p. 1326) improves the effectiveness of the decisions of the central agency. In our work, we obtain the same outcome by assuming that ICTs reduce c and k.

variable q and in the supply y for two reasons. First, as team coordination increases, the likelihood that the production scale remains at the predetermined level reduces. Second, as more precise signals allow firms to make their choices more responsive to signals (remember that $q^* (\mathbf{X}) = E_{\mathbf{V}|\mathbf{X}} (\mathbf{1V}) = \boldsymbol{\lambda}\mathbf{X}),$ this means that the ICT adoption in one sector may increase the environmental variability of upstream or downstream sectors, and, for the previous arguments, ICT adoption in these sectors. This conjecture can be interpreted as a mixture of 'stock' and 'epidemic' effects identified in the literature on the diffusion of new process technologies (Mansfield, 1963; Karshenas and Stoneman, 1993).

Often, the idea of team organization or *horizontal* organization is related to the concept of flexible organization. In our framework, this fact emerges directly by assuming routine when there is no team, and (partial) coordination when a team exists. Moreover, as a result of the previous assumptions on the role of ICTs, we conclude that ICTs improve the flexibility of the organization by increasing the level of coordination.

5 Conclusions

In this paper we have provided an illustrative analysis of a way to organize teams called 'management by exception': The team's members are instructed to follow a procedure which prescribes: how much information they have to collect; how to identify ordinary/exceptional situations; and how to make decisions. Depending on the type of situation, the procedure distinguished two different regimes: a coordination regime (in *exceptional* situations) and routine regime (in *ordinary* situations). We have proposed two different procedures providing an optimal level of information acquisition and team coordination based on a different definition of *exceptional* situations. The first procedure appears to be more efficient for small teams and low acquisition costs, and second one for large teams and low processing costs. Cost parameters and environmental variability affect the choice of the optimal procedure and the teamwork feasibility. We have also shown that declining ICT costs impact on the team design, promoting teamwork in the organization.

The model presented here can be extended in several ways. First, the management by exception practice can be analyzed using alternative and more complex procedures, which can include different degrees of hierarchical organization and/or different coordination rules. For example, the number of regimes can be expanded and intermediate levels can be introduced. Second, the set-up can be enriched by analyzing the case of correlated signals (which is only informally considered) or by increasing the number of decision makers. Third, the analysis will also benefit from the introduction of a dynamic set-up and explicitly considering the information processing tasks (e.g. considering parallel processing). Finally, some results of the paper should be tested in order to verify their empirical validity.

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6 Figures

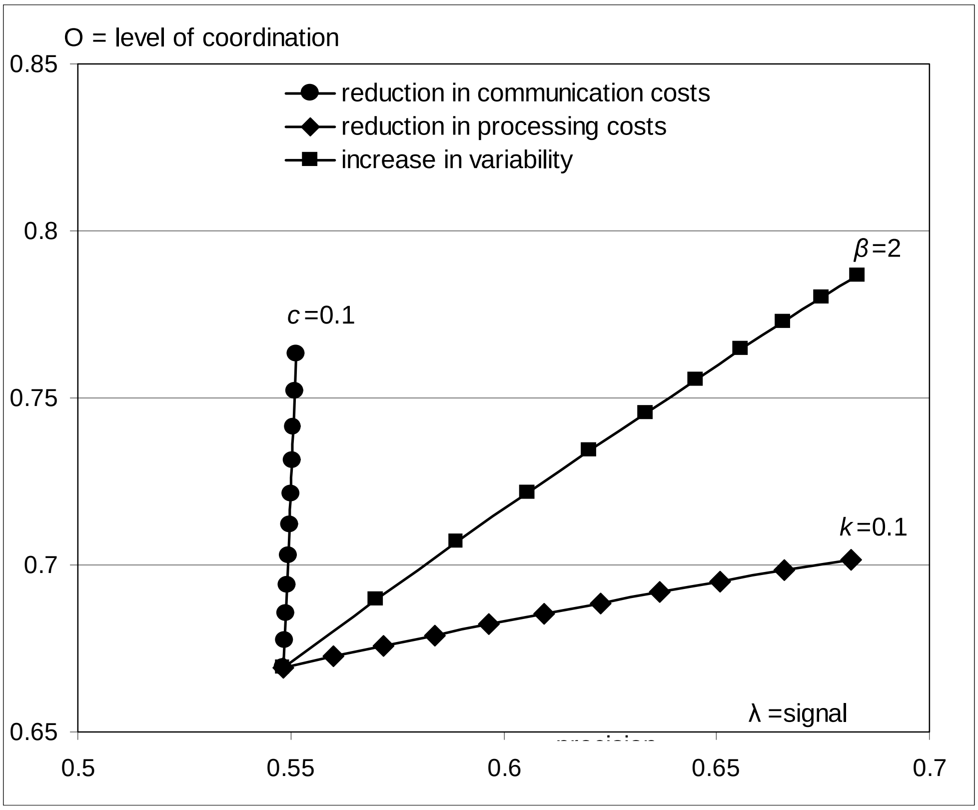

Figure 1: The picture presents the optimal level of coordination O^*, and of information acquisition λ^*, for procedure Proc I. Three paths with the same starting values ($c = k = 0.2$ and $\beta = 1$) are presented. The first path, describes the changes in O^* and λ^* when c moves from 0.2 to 0.1. The second path looks at a change in β from 1 to 2, and the third one shows a reduction in k from 0.2 to 0.1.

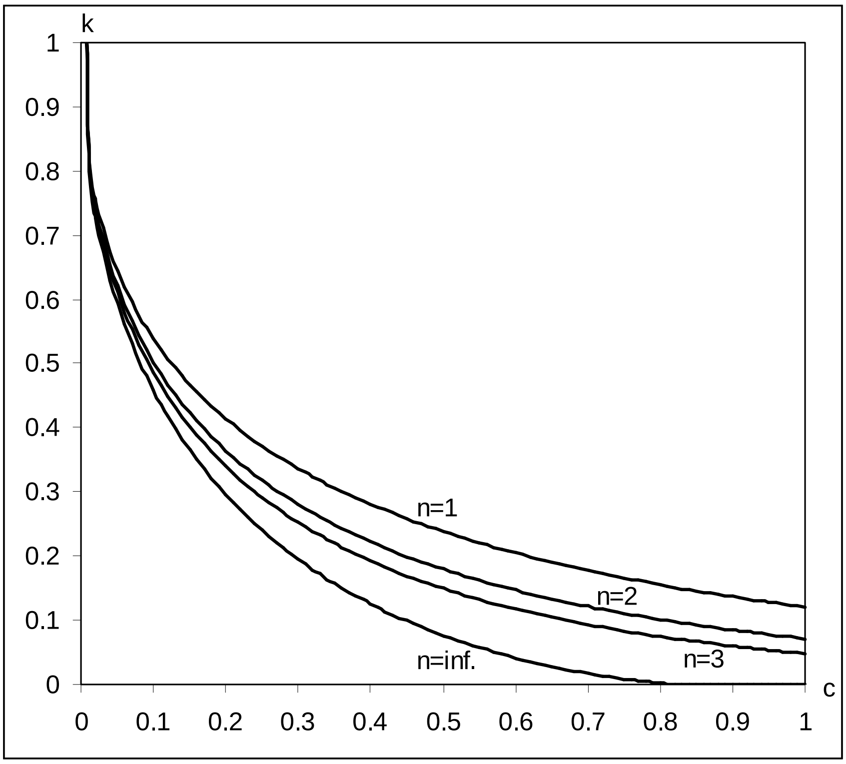

Figure 2: This figure depicts the thresholds for which a team of 1, 2, 3 or an infinity of agents is feasible under Proc I.

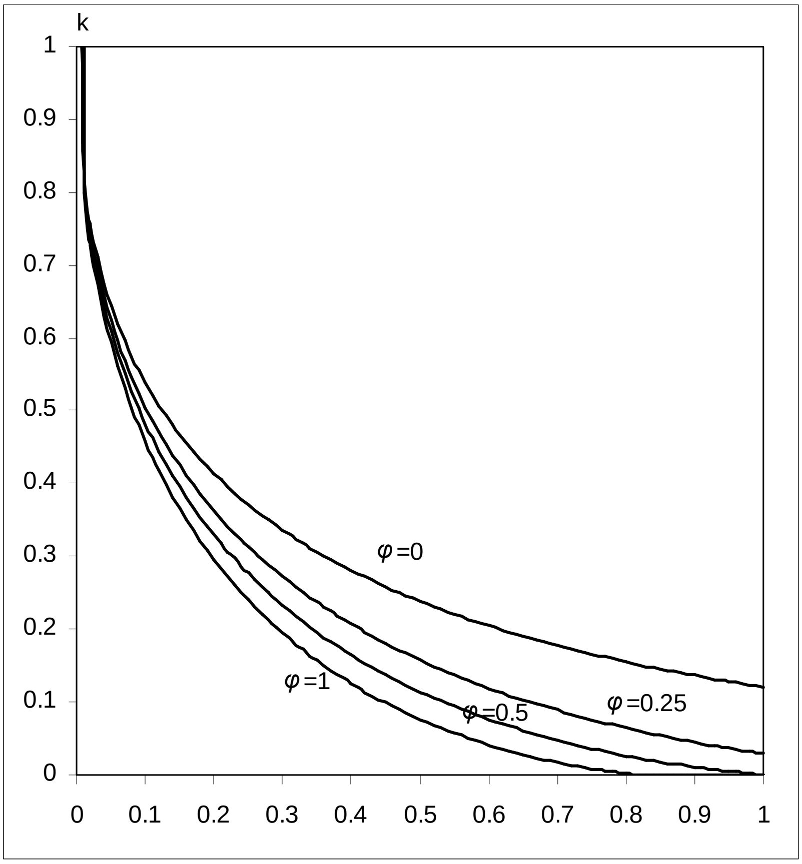

Figure 3: This figure depicts the thresholds for which a team is feasible under Proc II when the share of the costs for combining information with respect to the overall processing costs is: 0, 0.25, 0.5 and 1.

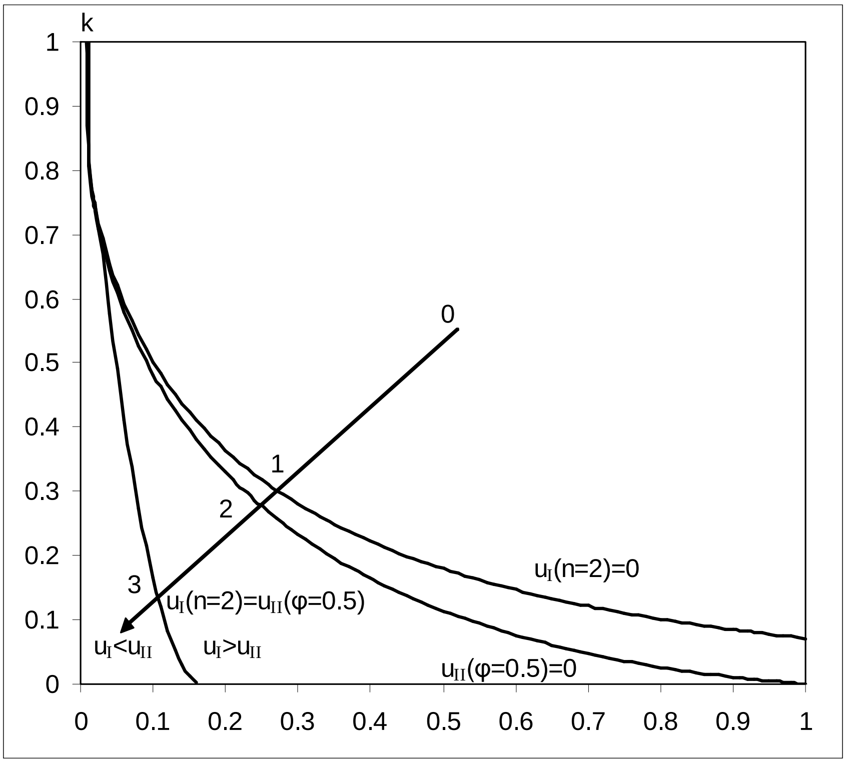

Figure 4: This figure compares Proc I with Proc II when $n = 2$ and $\varphi = 0.5$. For these parameter values, it emerges that Proc I is preferred to Proc II for large values of c and k, and Proc II is preferred to Proc I for small values of c and k. In addition, this figure presents a possible path of the organizational change due to a reduction of c and k. At time 0, since there are high processing and communication costs, activities are organized in a routine regime (and there is no team). Afterwards (between times 1 and 2), since there is a reduction in processing and acquisition costs, there is team formation organized under Proc I. Between times 2 and 3, the team can also be organized using Proc II, although Proc I is more profitable. Finally (at time 3), Proc II becomes more efficient.

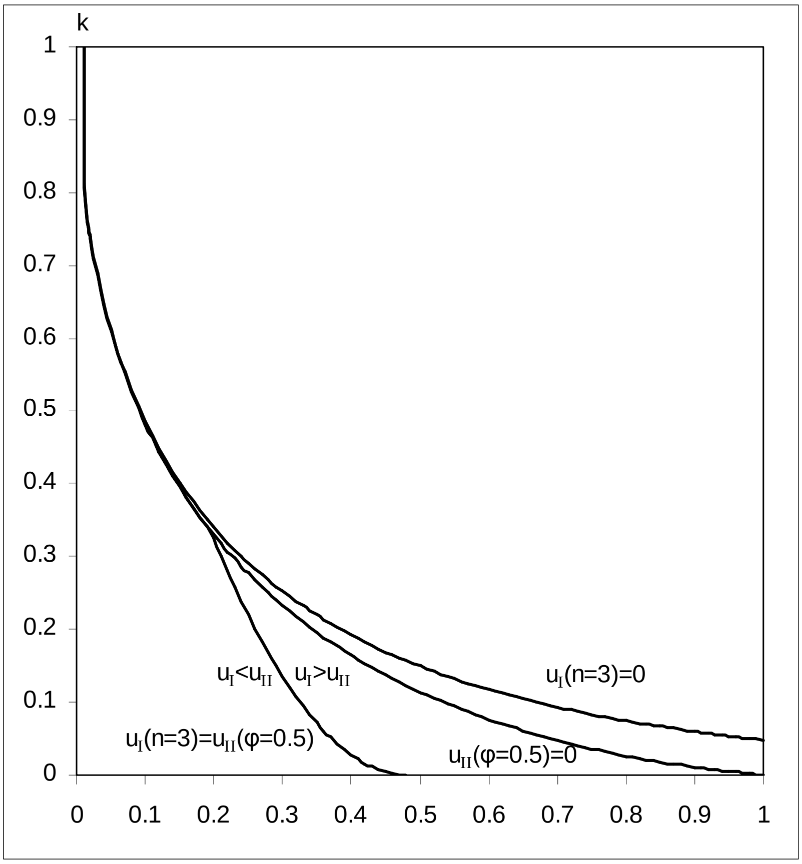

Figure 5: This figure compares Proc I with Proc II when $n = 3$ and $\varphi = 0.5$.

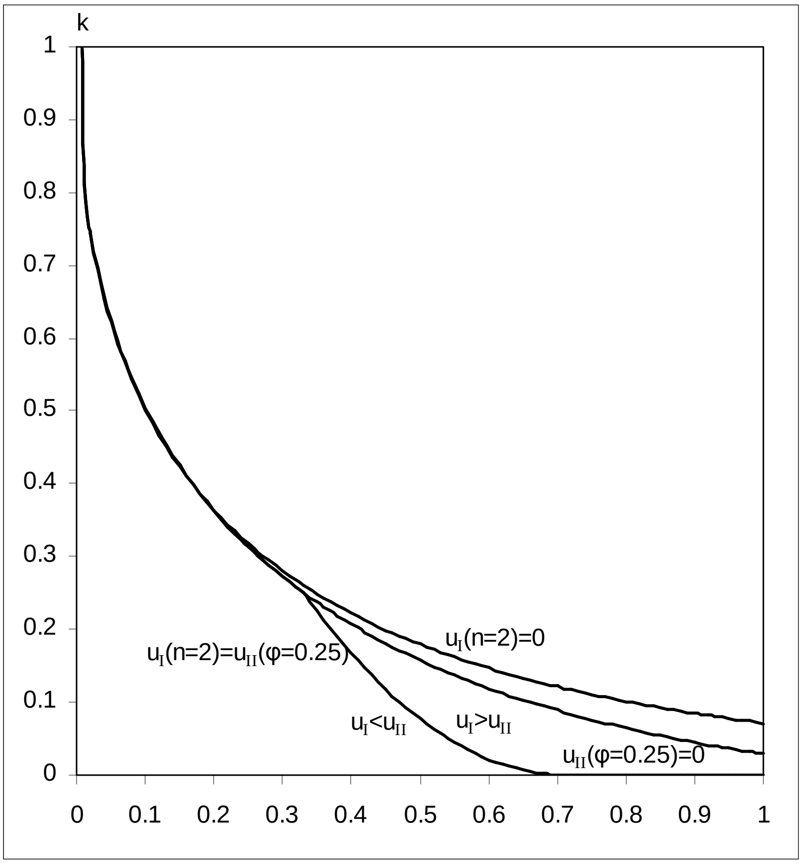

Figure 6: This figure compares Proc I with Proc II when $n = 2$ and $\varphi = 0.25$.