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ENVIRONMENT MONITORING AND  
ORGANIZATION STRUCTURE I

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Working Paper no 70

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September, 1987

## ENVIRONMENT MONITORING AND ORGANIZATION STRUCTURE I

### 1. The Problem Addressed

When discussing the theory of organizations, the issue of incentives has received a lot of attention. A huge literature appeared in the last years dealing with this problem. Here I will leave this question aside and concentrate on the problem of designing organizations in an efficient way. In fact the results can be looked at as establishing the attainable set of designs for organizations with memory, in a dynamic environment. As will be seen certain simple desirable properties will limit the choices of the designer.

Sah and Stiglitz (1985) in a recent paper present their discussion of the relation between organizational forms and the aggregation of errors in organizations. They impose an exogeneously given design and analyse how different types of organizations (polyarchies and hierarchies) aggregate type I and II errors in simple binary decisions (accepting or rejecting projects that can be good or bad). Their discussion puts the emphasis on the decision-related motivations to pick one design over another. Every unit has the same information (same probability of mistake) independently of its place in the structure, and all units are equal, performing the same task.

In many real organizations (e.g. business firms) there seem to be an altogether different set of reasons influencing the choice of designs. Namely informational issues. Certain units will have special capabilities to gather certain types of information (e.g. about market opportunities, or technology) and/or perform certain types of actions. This leads naturally to a specialization, where different units (departments) will be assigned different tasks.

The theory of teams deals with the relation between information structures and the design of organizations. But the work that has been done starts almost always from a given information structure and studies the decision-rule (one for each members of the team) that maximizes the expected pay-off of the team. The question of which information structures can be chosen, which are best and why, is left pretty much untreated.

Here I introduce a dynamic setting and impose a condition of "informational stability". It is not economic to accumulate more and more information (eventually irrelevant) as time goes by. But on the other hand, the relevant information must not be allowed to disappear (completely) in time. Each unit or department will be seen essentially as collecting and keeping specialized information, that can be transmitted to other departments or to the central manager. I will concentrate on the informational role of the units, and will admit that all decisions are concentrated at the centre. This will not avoid the need of

messages from department to department.

The analytical tools used here and some of the concepts were developed for the study of finite sequential machines (see Stearns and Hartmanis (1966)). In that literature the assignment problem is very close to the issues discussed below.

## 2. The Modelling Strategy

An organization - the firm, from now on - is seen as a set of departments. Each department is a unit gathering, processing and keeping information. This information is transmitted to a top management unit (the manager) and eventually to other departments. The manager makes all the decisions.

The decisions must be made today, based on current information. They generate a pay-off in the next period, that will depend on the state of nature that materializes at that time.

Take the set of possible states of nature,  $S$ , to be finite and invariant in time. The decision must then be made based on the best prediction available about next period's state of nature. Heisenberg notwithstanding, I will assume that, if I know the current state of nature and observe the current environment in sufficient detail (including the firm and other agents decisions), the state in the next period can be exactly predicted.

Initially no limits will be set on the capacity each department has to observe the current environment. Then all uncertainty about the next period state of nature is due to some ignorance about the present state of nature.

The firm can thus be seen as a dynamic system monitoring the state of the world. The state space of this dynamic system can be identified with  $S$ . We can then think of  $S$  as containing all relevant information (including past history) that, together

with current observation of the environment is enough to compute the evolution of the system.

Each department contains a certain number of people. To make things precise assume that each person is assigned a two block partition on  $S$ . Then a department with  $n$  people will be able to distinguish in which block of a partition with  $2^n$  blocks (maximum) is the state of nature. With enough people with such limited information I can know exactly which state of nature prevails.

However, the relevant knowledge for decision-making is next period state of nature. One can think of everybody computing in which block of "his" partition we will be next period. In general each person will have to know the personal information of everybody else to make that computation. This is exceedingly demanding and I would say impossible for many real situations. The fact that in the real world organizations tend to structure themselves in several departments is a clear sign that this trivial solution of having just one department with everybody communicating with everybody else is a costly one.

I will assume then that organizing the firm in one big department is a costly solution due to the complexity of the flow of information among members of the organization and also because of the huge amount of information each member has to use in updating his knowledge.

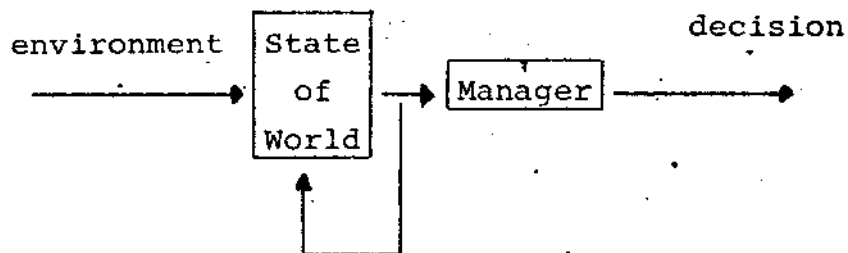


Fig. 1

Identify a department with a partition on the set of states of nature. The question then is whether we can decompose the big department in smaller ones, without losing the information the manager needs to take his decisions. These smaller departments, if we are to obtain a reduction in costs, would ideally be able to operate independently, as far as computing the next state is concerned.

### 3. Dynamic Independence

Make  $S$  the set of possible states of nature,  $Z$  the set of possible observations from the current environment, and  $\delta: S \times Z \rightarrow S$  the next state function. The optimal decision to be taken by the manager, upon receiving the (exact) prediction of the next state is  $d(\delta(z, s))$ , where  $z \in Z$ ,  $s \in S$  and  $d \in D$ , a set of possible decisions.

A partition  $\pi = \{B_1; B_2 \dots B_k\}$ , on  $S$ , where  $B_j$  is a block of the partition, is then identified with a department. Its task is to inform the center about which block of  $\pi$  the state of nature in next period is going to be.

Definition 1: a partition  $\pi_1$  is finer than  $\pi_2$  if each block of  $\pi_1$ , is a subset of a block of  $\pi_2$ . We write  $\pi_1 \leq \pi_2$ .

This relation "finer than" introduces a partial ordering in the set of all partitions of  $S$ . Clearly a finer partition gives more information about the state of nature than a coarser one.

Call  $\pi_0 = \{\bar{s}_1; \bar{s}_2; \dots; \bar{s}_n\}$  the finest partition, each block having exactly one state. This partition gives full information about the state of nature. And call  $\pi_I = \{\overline{s_1 \dots s_n}\}$ , the coarsest partition, with all states in just one block. The information given by  $\pi_I$  is said to be null.

Definition 2: the product of two partitions  $\pi_3 = \pi_1 \cdot \pi_2$  is the partition whose blocks are the intersections of each block of  $\pi_1$  with each block of  $\pi_2$ .

Definition 3: the sum  $\pi_4 = \pi_1 + \pi_2$  of two partitions is a partition whose blocks are formed in the following way. Two states  $s_i$  and  $s_j$  belong to the same block of  $\pi_4$  if they belong to the same block of  $\pi_1$  or to the same block of  $\pi_2$ .

Notice that  $\pi_1 \leq \pi_2$  iff  $\pi_1 \cdot \pi_2 = \pi_1$  and also

$$\pi_1 \leq \pi_2 \text{ iff } \pi_1 + \pi_2 = \pi_2$$

For a more detailed analysis of the algebraic structure of the set of partitions, see Stearne and Hartmanis (1966).

Take now a simple case, where  $S$  has four states. Define

$$\pi_1 = \{\overline{12}; \overline{34}\} = \{B_1; B_2\} \quad \text{department A}$$

$$\pi_2 = \{\overline{13}; \overline{24}\} = \{B'_1; B'_2\} \quad \text{department B}$$

If two departments are created, in charge of monitoring  $\pi_1$  and  $\pi_2$  respectively, the manager will have all the information he needs. The department A however knows only whether the current state is in  $B_1$  or  $B_2$ . Suppose  $s \in B_1$ . In general  $\delta(z,1)$  and  $\delta(z,2)$  need not both belong to  $B_1$  or  $B_2$ . In fact to compute whether next state is in  $B_1$  or  $B_2$ , department A will need the information of department B. Department A could operate independently of department B if (i)  $\delta(z,1)$  and  $\delta(z,2)$  would always belong to the same block of  $\pi_1$ , and (ii)  $\delta(z,3)$  and  $\delta(z,4)$  also belong to the same block of  $\pi_1$ .

Definition 4: Dynamic Independence: a department identified by the partition  $\pi = \{B_1 \dots B_k\}$  is dynamically independent if

$$\delta(z, s) \in B_j \text{ when } s \in B_k, \forall z \in Z$$

Take any dynamically independent partition. Then knowing in which block of  $\pi$  the state of nature currently is, I will know in which block it will be in the next period. The partition represents a piece of information that is stable in a certain sense as time passes.

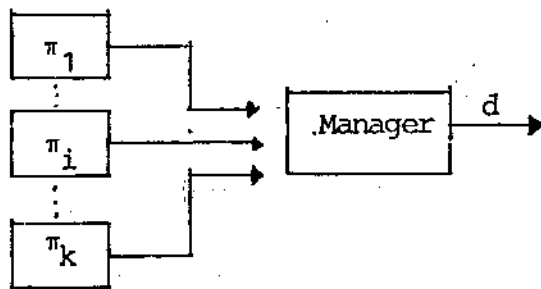
The possibility of designing the firm as a pure hierarchy or pure polyarchy is easily discussed in this framework.

Proposition 1: a pure polyarchy with K departments is possible if there are dynamically independent partitions  $\pi_1; \dots; \pi_k$ , such that  $\prod_{i=1}^k \pi_i = \pi_0$ .

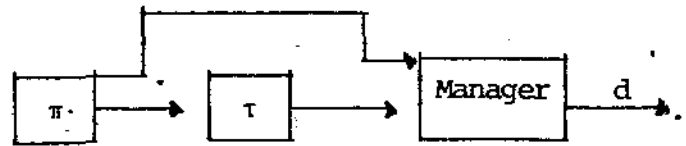
It is enough to identify each department with one of these partitions.

Proposition 2: a pure hierarchy, with two levels is possible if there is one dynamically independent partition  $\pi$ .

The first department is identified with  $\pi$ . It can operate without receiving any information from other departments. Choose then a partition  $\tau$  such that  $\pi \cdot \tau = \pi_0$  and identify a second department with  $\tau$ . This second department will need to receive information from the first one, for it is not dynamically independent.



a) Pure Polyarchy



b) Pure Hierarchy (two level)

Fig. 2

Notice that, if the biggest block of  $\pi$  has  $m$  states then  $\tau$  needs  $m$  blocks.

The existence of possible decompositions in a pure hierarchy with several levels can non be easily established. Suppose we have a set of dynamically independent partitions  $\pi_1 \geq \pi_2 \geq \pi_3 \dots \geq \pi_k = \pi_0$ . Then assign to department 1 the partition  $\pi_1$ . This department can operate independently. Assign to department 2 a partition  $\tau_2$  such that  $\pi_1 \tau_2 = \pi_2$ . Then department 2 will need information from department one in order to operate. But needs no additional information, for  $\pi_2$  is dynamically independent. The argument can be repeated, by defining  $\tau_i$  such that  $\pi_{i-1} \cdot \tau_i = \pi_i$ ,  $i=2, \dots, K$ . Notice that the department at level  $i$  receives information from all departments at levels  $j < i$ . This argument leads to

Proposition 3: a pure hierarchy with  $K$  levels is possible if there are  $K$  dynamically independent partition:

$$\pi_1 > \dots > \pi_k = \pi_0.$$

The set of all dynamically independent partitions can be easily seen to form a lattice, where the greatest lower bound of  $\pi_1$  and  $\pi_2$  is  $\pi_1 \cdot \pi_2$  and least upper bound is  $\pi_1 + \pi_2$ . Actually it is a sub-lattice from the lattice of all partitions. This means that, if  $\pi_1$  and  $\pi_2$  are dynamically independent, then  $\pi_1 + \pi_2$  and  $\pi_1 \cdot \pi_2$  are also dynamically independent. The structure of this lattice gives the information needed to generate all the attainable hierarchical-polyarchical designs. A more general class of designs allows for feed-back information flows, where a department receives information from another, but must also feed it some information back. This class of designs is not described by dynamically independent partitions.

A small example gives the gist of the argument. Suppose that the lattice of all dynamically independent partitions is given by the figure below:

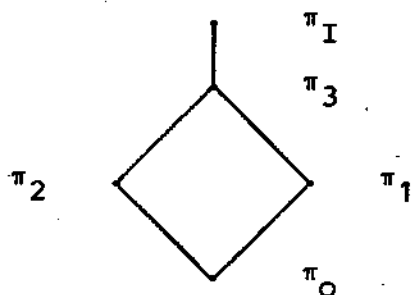


Fig. 3

A polyarchical decomposition is possible because  $\pi_1 \cdot \pi_2 = \pi_0$ . But the department 2 can be further decomposed as an hierarchy. In fact  $\{\pi_3, \pi_2\}$  form a sequence of dynamically independent partitions and an argument similar to the one used in Proposition 3

shows that department 2 can be organized in a department 3, to which is assigned  $\pi_3$  and a department 2' to which is assigned  $\tau_2$ , such that  $\pi_3 \cdot \tau_2 = \pi_2$ .

Similarly, department one can be organized as a two-level hierarchy by using department 3 and a department 1' in charge of  $\tau_1$ , such that  $\pi_3 \cdot \tau_1 = \pi_1$ . Then one possible design is

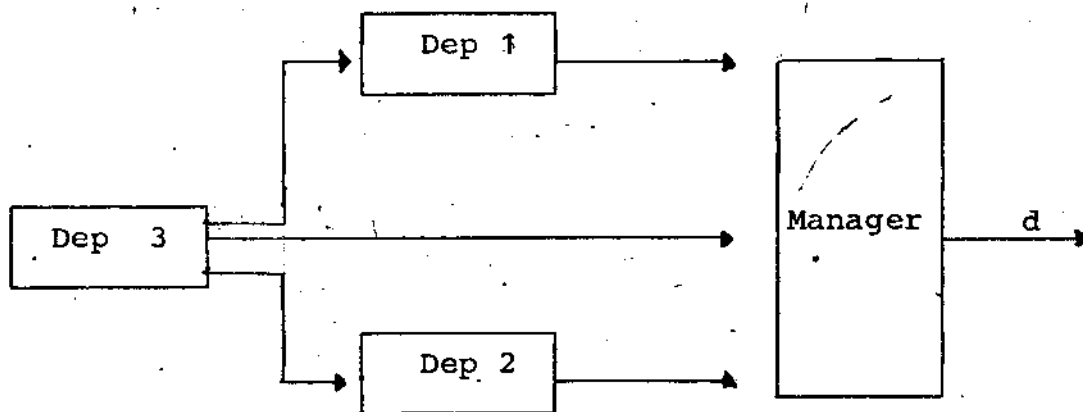


Fig. 4

#### 4. Decision and Size

It is possible to reduce the size of the problem, and the overall size of the organization, by noticing that the objective of this exercise is to allow the centre to get all the information it needs to reach a correct decision. If two states of nature lead to the same decision it is not useful to be able to distinguish one from the other.

Definition 5: two states are decision-equivalent if they lead to the same decision.

This relation is an equivalence relation and so introduces a partition,  $\pi_\epsilon$ , on the set of the states of nature. For decision taking this last partition is as useful as the full information partition. In general there will be less blocks in  $\pi_\epsilon$  than there are states of nature, and this can be looked at as a reduction in size of the set  $S$ , leading to a smaller organization.

It is tempting to isolate then the sublattice of the partitions that are coarser than  $\pi_\epsilon$ , take this as the universal set and disregard all the rest.

In general, however, this is not possible because the information in  $\pi_\epsilon$  does not allow to compute in which block of  $\pi_\epsilon$  we will be next period. In other words, to isolate the smaller problem by using  $\pi_\epsilon$ , it would be necessary that  $\pi_\epsilon$  be dynamically-independent. If this is so there is never a point in distinguishing one from the other the states in the same block of  $\pi_\epsilon$ . We have

all the information needed to follow the dynamics at this "aggregate" level, and all the information relevant for decision.

Proposition 4: If  $\pi_\epsilon$  is dynamically independent the set of states of nature,  $S$ , can be reduced to the set  $S'$  of the blocks of  $\pi_\epsilon$ .

In general we cannot expect this to happen. But we must take a dynamically-independent partition to meaningfully isolate a smaller problem. And we need to generate enough information to compute in which block of  $\pi_\epsilon$  we will be.

Definition 6: a partition is output-sufficient if the optimal decision is the same for any two states in the same block of the partition.

The set of all output-sufficient partitions is simply the set of all partitions finer than  $\pi_\epsilon$ . We are then looking for a partition that is simultaneously dynamically-independent and output-sufficient; call  $S_E^D$  the set of all such partitions.

Proposition 5: the set  $S_E^D$  is closed in relation to the addition and multiplication of partitions, i.e. they form a lattice.

This lattice is obviously a sub-lattice of all the dynamically consistent partitions:

If  $S_E^D$  is a lattice it has a maximal element,  $\pi_E^D$ . We can now use  $\pi_E^D$  to isolate a smaller problem of design organization in a consistent way. The information passed to the center is

somewhat in excess of what is strictly needed, and in that sense we have an inefficiency in the use of information. The problem arises because the information is needed for the current decision and also to keep track of the "dynamics" of the system. Even if we accept to do this tracking in an aggregate way (by keeping track only of blocks of a partition), we cannot use an arbitrary aggregation.

Marshak and Radner (1972), introduced a similar concept, the payoff-adequate partition. In their problem the payoff depends on the decision and the state of nature that materializes, and two states are in the same block of this partition if the payoff is the same, whatever decision is taken. Here we require only that the optimal decision be the same. As long as that is true, the payoff is the maximum possible, whether it depends also on the state of nature or not (in which case the two definitions coincide).

## 5. Decentralizing Decisions: The Polyarchy Case

Until now we assumed that the "centre" was a monolithic part of the design, where all decision taking is concentrated. We will now lift this hypothesis and try to study under what conditions we can decentralize (part of) the decision to a manager that receives information from only a subset of the departments.

Suppose then that the decision is a vector  $\underline{d} = (d_1 \dots d_M)$ , where  $d_i$  refers to variable  $i$ . Assume that  $d_i$  can take only a finite number of values, so the decision set keeps finite. The question asked is: under what circumstances can we allow a manager receiving reports from a subset of the departments be responsible for a subset of the decision variables? The following definition will be useful in answering this question.

Definition 6: the partition  $W_i$  is sufficient for the decision variable  $d_i$ , if the value of  $d_i$  implicit in the optimal  $d^*$  is the same for any two states in the same block of  $W_i$ .

If  $W_i$  is sufficient for  $d_i$ , then a decision maker knowing which block of  $W_i$  will materialize can pick optimal  $d_i$  without reference to what are the values of  $d_j$ ,  $j \neq i$ .

Notice that  $\prod_i W_i = \pi_e$ , by definition of  $W_i$  and  $\pi_e$ .

Take now the case where the organization was designed as

a polyarchy. In that case we have, say,  $K$  departments defined by  $K$  dynamically-independent partitions, such that  $\prod_{j=1}^k \pi_j \leq \pi_\epsilon$ . "A fortiori",  $\prod_{j=1}^k \pi_j \leq W_i$ , and the decision maker in charge of  $d_i$  can choose its correct value if he receives all the information. He is able to make the same decision by receiving only information from a (proper) subset,  $\mathcal{D}_i$ , of the departments, if  $\prod_{j \in \mathcal{D}_i} \pi_j \leq W_i$ . This condition allows for a certain degree of decentralization, but it is not enough for the existence of a separation of decisions by departments.

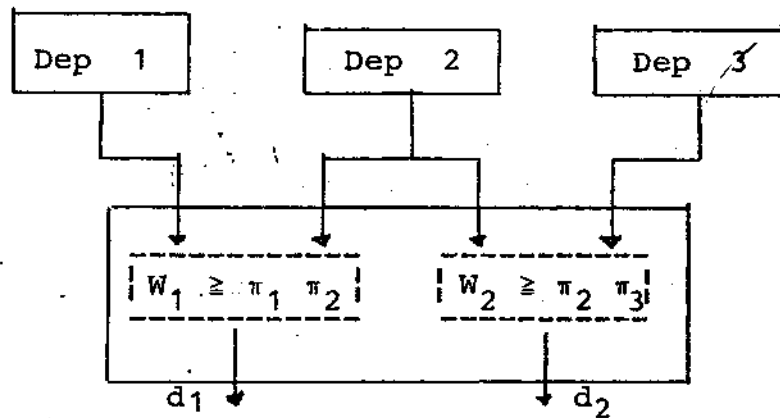


Fig. 5

The figure above represents such a situation. Here  $W_1 \geq \pi_1 \pi_2$  and  $d_1$  can be chosen by someone to whom Dept. 3 does not report. Similarly  $W_2 > \pi_2 \pi_3$ , and the second decision maker can be made independent of department 1.

Notice that in this case it is always possible to have a sub-manager to whom both department two and three report. This manager decides on  $d_2$  and must transmit enough information of the centre ( $\pi_2$ ) so that decision  $d_1$  can be taken. In this example

$\pi_2$  is enough for that. In general it may be an aggregation of  $\pi_2 \cdot \pi_3$ .

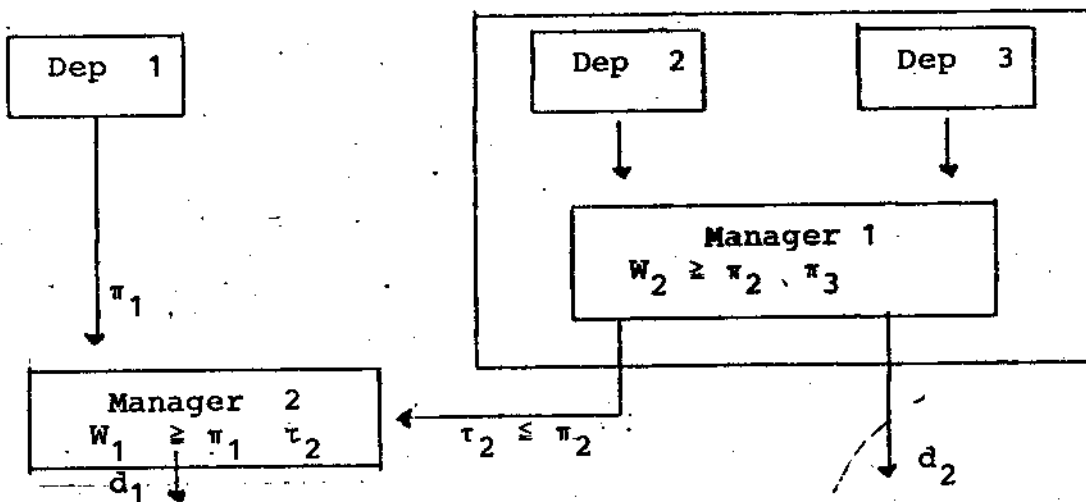


Fig. 6

With such an arrangement, the decision  $d_2$  has been decentralized. Notice that it would have been possible to make the inverse arrangement, with  $d_1$  decentralized and  $d_2$  taken at the centre.

Proposition 6: a decision  $d_i$  is decentralizable: iff there exists a proper subset  $\mathcal{D}_i$ , of  $\mathcal{D}$ , such that

$$W_i \geq \prod_{j \in \mathcal{D}_i} \pi_j.$$

If all decisions are decentralizable, then we may consider designs where there is no centre, in the sense that full information is never concentrated in one manager. That is the case depicted in last figure. What we called "center" is in

fact a second manager, who is in charge only of  $d_1$ . However he receives a given message from the first manager. If we see this message as a "reporting" function, it is natural to assume a hierarchy in which manager 2 is the "boss", and so keep the word centre to describe his position. In the absence of incentive problems, there is no reason to associate a hierarchy with message transmission. We will say then, that an organization is decentralizable if it does not need a centre where full information is concentrated.

Proposition 7: an organization is decentralizable iff all variables  $d$  are decentralizable.

Call division to a set of departments that report to the same manager. Then Fig. 6 can be reinterpreted as an organization with two divisions. The first has department 1 only, and is in charge of  $d_1$ . The second is charge of  $d_2$  and includes departments two and three. However division two must provide some information to division one.

This leads naturally to the question of independence of these divisions. From the point of view of monitoring the state of the world each department, and "a fortiori" each division, is completely independent from the others. But there are externalities in the use of the information available at department level for decision making purposes. If we could eliminate these externalities at division level, we could have in fact a set of totally independent organizations each in charge of a group of

decision variables, i.e. the whole organization would be separable:

Take  $\mathcal{D}$  as the set of all departments and form two subsets  $\mathcal{D}_1$  and  $\mathcal{D}_2$  such that  $\mathcal{D}_1 \cup \mathcal{D}_2 = \mathcal{D}$  and  $\mathcal{D}_1 \cap \mathcal{D}_2 = \emptyset$ . Suppose also that we can make a partition of all the decision variables in two disjoint sets  $D_1$  and  $D_2$  in such a way that  $\prod_{j \in \mathcal{D}_1} \pi_j \leq \prod_{j \in \mathcal{D}_2} W_j$  for  $i=1,2$ . In this case the information gathered by the departments in  $\mathcal{D}_1$  is enough for deciding about all variables  $D_1$ , and the information gathered by the department in  $\mathcal{D}_2$ ,  $j \neq 1$ , is irrelevant for that purpose. We can then have two totally independent organizations.

Proposition 8: an organization is separable in  $N$  independent ones iff we can find  $N$  sets  $\mathcal{D}_i$  of departments such that  $\mathcal{D}_i \cap \mathcal{D}_j = \emptyset$  and  $\bigcup_i \mathcal{D}_i = \mathcal{D}$  and corresponding sets of decision variables  $D_i$ , such that  $D_i \cap D_j = \emptyset$  and  $\bigcup_i D_i = D$ , such that

$$\prod_{j \in \mathcal{D}_i} \pi_j \leq \prod_{j \in \mathcal{D}_i} W_j.$$

This discussion suggests an interesting way to characterize a department that must always have a role as "staff". By this we mean that it can never be part of a division to which some decisions are delegated. Take the case where  $d_1$  is not decentralizable, but the set  $\{d_2 \dots d_M\}$  is. Assume furthermore that the  $k$  first partitions are not relevant for  $\{d_2 \dots d_M\}$ , i.e.  $W_2 \dots W_M \geq \prod_{j=l+1}^k \pi_j$ . We can then form a division with departments  $l+1 \dots k$ , deciding on  $d_2 \dots d_M$ , and giving information to the centre. We need always a centre, for  $d_1$  is not decentralizable. Then the role of

departments  $\pi_1 \dots \pi_\ell$  is simply to give information to the central manager so that he can choose  $d_1$ . No design is possible that does not have this feature.

Definition 7: take  $D_1$  as the set of non decentralizable decisions, and assume without loss of generality that  $\prod_{j \in D_1} W_j \leq \prod_{j=l+1}^k \pi_j$ ,  $l \geq 1$ . If  $D_1$  is non empty the departments  $\pi_1 \dots \pi_l$  are staff departments of the central manager.

The division in charge of the decisions in  $\bar{D}_1$  can be looked at as an organization in its own right; Some of the departments integrating this division can be now "staff" departments, if we apply the definition above, taking  $\bar{D}_1$  as the new universal set of decisions. By successive applications of the definition we can identify all the departments that are staff. By our definition a department that is not so classified, may however be used as such, in a given design.

## 6. Decentralization in a Hierarchy

Decentralization of decisions in a hierarchy can be analysed in a similar way. The important difference is that the departments have already well defined links, due to the need of keeping the relevant information to follow the dynamics of the system. Take then  $\pi_1 \geq \pi_2 \geq \dots \geq \pi_k = \pi_0$  and the relevant dynamically-independent partitions, and  $\tau_1 = \pi_2, \dots, \tau_k$  as the partitions defining the K departments ( $\tau_1 \dots \tau_\ell = \pi_\ell, \ell = 1 \dots K$ ).

If, say,  $\tau_2 \tau_3 \leq W_1$ , we could isolate departments two and three and decentralize decision 1 to these departments. But for other purposes department one must go on giving information to both departments two and three. It is natural then, for the manager deciding  $d_1$ , to have authority over department one also. If one take the hierarchy defined by the set  $\{\pi_1 \dots \pi_k\}$  as a restriction, the question is how far down the hierarchy can a decision be pushed. Call  $\ell(d)$  that level. Simple reflexion shows that  $\ell(d) = \max_{\ell} \{\ell \mid \pi_\ell \leq W_1\}$

Call now  $D_j = \{d_j \mid \ell(d_j) = j\}$ , the set of decision that can be taken at level j. If we assign a manager to each level j for which  $D_j$  is non-empty we have decentralized ("pushed down the organization") as much as possible, given the set  $\{\pi_1 \dots \pi_k\}$  used to define the hierarchy. The manager will receive information from all departments i, such that  $i \leq j$  and take all the decisions in  $D_j$ .

## 7. Redundant Observations

Until now we have assumed that all departments would make the same observations about the current environment. In general there is some cost associated with each department observations, and it is natural to assume that the cost is higher, the more detailed is the observation. We should then limit the observations of each department to what is strictly necessary. These observations are used to compute the blocks of the relevant partition in which the state of nature will be next period. But for some partitions full observation may be useless and thus inefficient. We need only consider designs where departments never make useless observations. Take then  $Z$ , the set of all possible observations, and  $\lambda$  a partition on  $Z$ . The dynamically-independent partition  $\pi_i$  is used to define the structure of the organization. By the dynamic independence property we know that all states in the same block of  $\pi_i$  will lead to states in the next period that belong also to the same block of  $\pi_i$ . But, for different values of  $z$ , this image-block is, in general, different. If,  $z_1$  and  $z_2$  lead always to the same block of  $\pi_i$  the department characterized by  $\pi_i$  has no point in distinguishing one from the other. It is equivalent to observe  $z_1$  or  $z_2$ .

Definition 8: two observations  $z_1$  and  $z_2$  are  $\pi_i$  - equivalent if  $\delta(z_1, B_j) \subset B_k \iff \delta(z_2, B_j) \subset B_k, \forall j$ , for some  $K$ .

We can now define a partition  $\lambda_i$  in the set  $Z$ ; by having all

observations  $\pi_i$  - equivalent in the same block of  $\lambda_i$ . Then  $\lambda_i$  is (minimum) amount of information about the current environment that department  $i$  needs, in order to keep track of the "dynamics of the system".

The decision-taking process imposes no restrictions on this amount of information. The decision depends only on the state of nature and not on the current observations. Then  $\lambda_i$  is really the amount of information about the environment the department  $i$  needs. More detailed observation is redundant, and thus inefficient.

## 8. Summary and Possible Extensions

The efficient design of organizations was analysed in the context of a dynamic environment. The emphasis was put on the informational role of each department: gathering, processing and transmitting information. Two different needs must be acknowledged. The first one results from the necessity to forecast the next period state of nature, for the current decision has effects only in the next period pay-off. The organization must keep enough information in order to "track" nature. This imposes some restrictions on the possible organizational designs. The hierarchical-polyarchical designs are analysed and the key concept of the analysis is the dynamic independence of a partition defined on the set of states of nature. The use of this concept allows the identification of the designs in which each department can be in charge of keeping track of a given piece of information, and do that independently of the others.

Not all such designs are efficient. The information is useful only if it affects the decision taking process. From this point of view we may need only to know some rather aggregate information. This fact can be used to eliminate inefficient designs. Together, the two conditions will define the "attainable set" of possible organizations.

Some points deserve a more careful analysis. The attention was here restricted to hierarchies and polyarchies. In any case,

if a department was providing information to another, this last one would not be allowed to feedback information to the former. The extension of the analysis to this case is done in a companion paper (Lucena (1987)). The emphasis is in the efficient use of information in the organization.

A second development, also presented in Lucena. (1987), extends the analysis in another direction. It may be the case that transmitting information from one department to another is very costly. A great emphasis should then be placed in reducing the "linkages". If there are no dynamically-independent partitions (or not enough of them) it may be impossible to have a pure polyarchy. By using the concept of a cover rather than a partition we extend the conditions under which a design based on a set of independent departments can be achieved.

Another maintained assumption could be usefully dropped. It is assumed throughout the analysis that the central manager will have an error free prediction of next period state of nature. As a consequence for any payoff function he is able to pick the best decision. Actually we worked directly with the relation between the forecast and the decision. The only thing that matters about the payoff function is which is the best decision associated with a given state. But the cost of generating this amount of information must be traded-off against the expected losses of making (sometimes) the wrong decision. It may be economically interesting to have a much simpler design, costing less, if the difference in the payoff associated with a mistake is not substantial.

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