Screening Efficiency of Networks

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Abstract: In this paper, we study screening efficiency of networks as organizations in comparison with polyarchies and hierarchies. Firstly, we briefly characterize these organizational architectures, then we rank them in the case of infinitely many and finitely many decisional units. As we show and discuss, networks are more efficient than polyarchies and hierarchical architectures with good initial choice portfolios. In opposition, whether Type II errors are very likely to occur, a hierarchy preforms better than polyarchies and networks. Finally, we illustrate how these organizations perform when a budget constraint has to be fulfilled.

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1 Introduction

Formal and informal networks are one of the real novelties of Information Age's societies and economies. From an organizational viewpoint, they are conceived as a new mode to organize economic exchanges, to take decisions and to process information in environments in which flexible and de-localized production takes place and knowledge management and sharing deeply characterize added value creation.

As well known, networks grant modular flexibility, assets complementarity, multilateral communication and dynamically synergic behavior[2], fundamental traits of organizations that want to cope with Information Age's highly dynamic and flexible economic and social contexts. Moreover, ICT-based networks provide real-time connections among de-localized decisional bodies or organizational units (Markus and Robey (1988), Lucas and Baroudi (1994)). Hence, not surprisingly, academics, firms' executives and R&D agencies's boards of directors have deeply discussed, during the last decade, under which conditions networking is a profitable organizational strategy (Radner (1992), Powell (1990), Nohria and Eccles (1994)).

Among economists, such a debate can be framed in the literature on hierarchies and polyarchies started by Simon's (1976) seminal contributions and on the research agenda during the 90ies because of an important paper by Sah and Stiglitz (1986). In that contribution, Sah and Stigltz analyze whether to concentrate or to distribute resources and control within organizations by comparing a hierarchy composed by two successive bureaus and a polyarchy defined as two *parallel* decision nodes able to exchange information. Both organizations assume decisions about projects' implementation and Type I and Type II errors can occur. In a hierarchy, decisions are centralized and approved projects are those accepted by both bureaus. In opposition, in polyarchic organizations, with decentralized control and resources, a project is implemented if and only if it has been positively screened by at least one decisional unit. Sah and Stiglitz to show that if we have poor (resp. rich) initial choice portfolio a hierarchical (resp. polyarchic) organization minimizes Type II errors (resp. Type I errors) and hence it is socially preferable.

Indeed, several refinements of Sah and Stiglitz (1986)'s model exist in the literature[3]. Nevertheless, so far, no contributions have tried to extend Sah and Stiglitz's model to network structures. Thus, in this article, we deal with such an extension to grasp some insights on the organizational issue: *whence*

[2] On networks as organizations see Van Alstyne (1997).

[3] For instance, Koh (1992) emphasizes that with variable evaluation costs screening capacities of hierarchies and polyarchies become respectively less and more effective at higher levels of complexity. Gersbach and Wehrspohn (1998) analyse relative performance of both organizational architectures in presence of a budget constraint on resources for evaluation and Ben-YaSahr and Nitzan (2001) study *robustness* of optimal organization architectures, i.e. relative sensitivity of screening efficiency to small changes organizations' size.

networking ? In doing this, we firstly characterize the three organizational architectures, then we build a Sah and Stiglitz-inspired set up where organizations have N decisional units or bureaus. As it will be argued, in terms of screening efficiency a network organization can perform better than a polyarchy in presence of well-endowed choice portfolios and not too many decisional units. Otherwise. the opposite result holds. Furthermore, consistently Sah and Stiglitz's results, whether Type II errors are very likely to occur a hierarchy preforms better that polyarchies and networks. As we'll argue, if we introduce a budget constraint in the problem the same conclusions hold.

The remaining of this essay is organized as follows. In Section 2, definitions and notation are introduced. In Section 3, basic results are presented and discussed, while the case with a budget constraint is briefly studied in Section 4. As usual, the last section concludes.

2 The Set-Up

Throughout this paragraph, we introduce definitions and notation.

Let us suppose to have N organizational identical units (*decisional nodes*) and a set L of communication flows (*links*) among them. Communication takes place with no frictions and costs.

An *organizational architecture* is a triple of: a set of decisional nodes, a set of linkages and an information diffusion mechanism. Let us consider three basic mechanisms: (a) an order relation among bureaus; (b) an homeostatic diffusion process among parallel polyarchic nodes and (c) a networked process of many-to-many communication.

Accordingly to Sah and Stiglitz's (1986), each decisional node screens randomly selected projects - with net value equal to $x \in R$ - from a feasibility set (*portfolio*). Each node decides to implement or reject projects. The density function of projects is given by $g(x)$ and each unit is characterized by a *screening function,* $p(x) \in [0;1]$, that determines the probability of acceptance. In a hierarchy, all projects are firstly evaluated by a lower bureau, then, only accepted projects are re-examined by higher bureaus. Differently, in a parallel polyarchy, each node examines independently all projects and those rejected by a decisional unit are re-examined by contiguous units. Finally, a network works like a polyarchy with the exception that rejected projects are contextually re-examined by all other network nodes[4].

More precisely, a *hierarchy* is defined as $H = \langle N; L; \geq \rangle$ with $l_{ij} \in L$ only if $i \geq j$ and $\nexists k$ such that $i \geq k \geq j$. Following Sah and Stiglitz's analysis, the probability that a project is implemented by this system is given by

[4] Trivially, $N > 3$ othersiwe no differences exist between a polyarchy and a network.

$f^{H(N)}(x) = [p(x)]^N$ and the number of expected implemented projects (*overall acceptance* henceforth) is given by $n^{H(N)} = \int f^{H(N)}(x)g(x)dx$.

Similarly, a *parallel polyarchy* is a triple $P = \langle N; L; D \rangle$ where D is a diffusion mechanism of the kind:

$$D := \begin{cases} l_{ij} \in L \text{ only if } d(x; y) = 1 \\ l_{ij} \notin L \text{ otherwise} \end{cases} \tag{1}$$

where d is a distance measure. In this case, system's overall acceptance is given by $n^{P(N)} = \int f^{P(N)}(x)g(x)dx$ with $f^P(N) = p(x) \left[\frac{1-(1-p(x))^{N+1}}{1-(1-p(x))} \right]$.

Finally, a *network* is defined as a triple $\Sigma = \langle N; L; V \rangle$ with $V := N \times N \to L$ and $l_{ij} \in L$ for $\forall i, j \in N$. Straightforwardly, networks' overall acceptance is equal to $n^{\Sigma(N)} = \int f^{\Sigma(N)}(x)g(x)dx$ with $f^{\Sigma}(N) = p(x) \left[1 + \frac{1-p(x)}{N-1} \right]$.

3 Comparative Performances

Let us proceed to the analysis of organizations' comparative performances in the case of identical screening functions. Let us firstly refer to a benchmark case with infinitely many decisional nodes. In the next subsection, we'll deal with a more traditional finite case.

3.1 Infinitely Many Decision Units

With infinitely many nodes, in order to rank above organizational architectures in terms of performances, we have to compare limit properties of $f^{s(N)}(x)$ for $s = H, P, \Sigma$. More precisely, it can be shown that:

$$f^{P(N)}(x) = p(x) \left[1 + (1-p(x)) + (1-p(x))^2 + ... + (1-p(x))^{N-1} \right] \underset{N\to\infty}{=}$$

$$\underset{N\to\infty}{=} p(x) \left[1 + \frac{(1-p(x))}{1-(1-p(x))} \right] = \frac{p(x)}{1-(1-p(x))} = 1 \tag{2}$$

$$f^{H(N)}(x) = [p(x)]^N \underset{N\to\infty}{=} 0 \tag{3}$$

$$f^{\Sigma(N)}(x) = p(x) \left[1 + \frac{1-p(x)}{N-1} \right] \underset{N\to\infty}{=} p(x) \tag{4}$$

Hence, we get:

Proposition 1 *With infinitely many decision units, the following ranking holds:*

$$n^P > n^\Sigma > n^H \tag{5}$$

Proof. Straightforward using expressions (2), (3) and (4). ■

Intuitively, in a parallel polyarchy communication relies on *one-to-the-neightbours* information flows and projects rejected by one unit (say k) are thereafter screened by nodes q and r with $d(k;q) = d(k;r) = 1$ for $\forall k \in N$. Then,.projects rejected by nodes q and r are analyzed again by contiguous nodes different by k. Homeostatic diffusion of information continues until a *next-door* decision unit exists. With infinitely many nodes very likely, sooner or later, a decisional unit will accept a project previously rejected by many other nodes. Let us call this effect *decisional redundancy.* Thus, Type I errors' probability increases with $N \to \infty$ and $n^{P(\infty)} = \int g(x)dx \to 1$.

Exactly the opposite occurs in a hierarchy. With infinitely many bureaus each possibility must pass through infinite checking. Reasonably, Type II errors are null and very likely we shall have absolute inaction (*i.e.* $n^{H(\infty)} \to 0$).

Finally, in a network *many-to-many communication* grants that those projects rejected by a node (k) are simultaneously screened by all other nodes. Hence, some of rejected projects will be chosen and remaining ones immediately dropped since commonly known. This reduces the number of re-evalutations of previously rejected items, decisional redundancy and overall acceptance with respect to a parallel polyarchy $\left(n^{\Sigma(\infty)} \in [0;1]\right)$.

3.2 The Finite Case

Following what we have done above, we can now compare our organizational architectures in the case of a finite number of decisional units. Using again (2), (3) and (4) for $N \in \mathbb{R} \geq 3$, we get:

Proposition 2 *With $N \in \mathbb{R} \geq 3$, the following ranking holds:*

$$n^\Sigma > n^P > n^H \tag{6}$$

Proof. For the first part of (6), it can be shown that

$$p(x)\left[1 + \frac{1-p(x)}{N-1}\right] > p(x)\left[\frac{1-(1-p(x))^{N+1}}{1-(1-p(x))}\right] \tag{7}$$

because

$$\frac{1}{p(x)} < 1 < \frac{N}{N-1} \tag{8}$$

Hence, $f^{\Sigma(N)}(x) > f^{P(N)}(x)$ and $n^{\Sigma} > n^{P}$. For the second part, we can write

$$p(x)\left[\frac{1-(1-p(x))^{N+1}}{1-(1-p(x))}\right] > [p(x)]^{N} \tag{9}$$

Manipulating (9), we get:

$$1 > (1-p(x)\frac{1}{N} \tag{10}$$

Expression (10) is always verified given our assumption on $p(x)$. ■

By comparing above results, we grasp some peculiarities of networked communication. With a finite set of network's nodes, many-to-many information flows make networks more receptive than polyarchies with homeostatic information diffusion. Hence, a stronger incidence of Type I errors can be easily predicted. However, the likelihood of Type I errors is softened by increasing network's dimensions. In such a case, lower decisional redundancy with respect to parallel polyarchies, where information diffusion is slow and iterated re-examination of rejected items frequent, reduces the probability to accept bad projects.

By joining previous propositions' insights, it is also possible to underline that hierarchies are preferable to polyarchies and networks with awful initial project portfolios, while, whether initial portfolios are very good ones, the opposite ranking holds. Furthermore, with excellent portfolios networks ensure a larger portions of accepted and implemented good projects than a polyarchy because of more effective communication. However, the opposite is true with infinitely many nodes and excellent portfolios: in such a case, an infinite polyarchy is preferable than a network with infinitely many nodes. Under this proviso, decisional redundancy becomes a device to grant minimal Type I errors as well as to avoid good projects rejection caused by myopic analysis or distorted screening processes. In contrast, whether feasible projects are largely of bad quality decisional redundancy augments more strongly Type I errors in an infinite polyarchy than in a similar network. In this case, the latter is better than the former.

4 Two Types of Projects and a Budget Constraint

In previous sections, we have compared the three organization architecture in terms of screening efficiency in absence of any constraint. This is a meaningful comparison if we consider polyarchies or networks as principles of systems' organization (societies, communities, economies). Nevertheless, constraints matter if we consider real world organizations. In particular, the economic literature has emphasized the importance of *budget constraints* defined as a maximum number of acceptable projects (M) Thus, we now compare networks and polyarchies performances in presence of a budget constraint[5]..

Following Gersbach and Wehrspohn (1998), we consider without loss of generality the two projects case fwith N finite.

Let us suppose to have two types of projects $(1,2)$ characterized by acceptance probabilities equal to $p_1 > p_2$ and net value given by $z_1 > z_2$. The proportion of good projects in the portfolio is denoted by $\alpha \in [0;1]$ and $1-\alpha$ indicates the percentage of bad projects. As above, the number of accepted projects for networks and parallel polyarchies are given respectively by $n^{\Sigma}$and n^P. Using (2) and (4), we can write budget constraints as follows:

$$\begin{aligned} M &= n^{P(N)}\left\{p_1\left[\frac{1-(1-p_1)^{N+1}}{p_1}\right]\alpha + p_2\left[\frac{1-(1-p_2)^{N+1}}{p_2}\right](1-\alpha)\right\} = \\ &= n^{P(N)}\Lambda^{P(N)} \end{aligned} \tag{11}$$

$$M = n^{\Sigma}\left\{p_1\left(\frac{N-p_1}{N-1}\right)\alpha + p_2\left(\frac{N-p_2}{N-1}\right)(1-\alpha)\right\} = n^{\Sigma(N)}\Lambda^{\Sigma(N)} \tag{12}$$

Hence, following Sah and Stiglitz (1986), expected values of approved projects for the two organizational architectures are respectively given by:

$$\begin{aligned} Y^{P(N)} &= n^{P}\left\{p_1\left[\tfrac{1-(1-p_1)^{N+1}}{1-(1-p_1)}\right]z_1\alpha + p_2\left[\tfrac{1-(1-p_2)^{N+1}}{1-(1-p_2)}\right]z_2(1-\alpha)\right\} = \\ &= n^{P(N)}\Omega^{P(N)} \end{aligned} \tag{13}$$

$$\begin{aligned} Y^{\Sigma(N)} &= n^{\Sigma}\left\{p_1\left(\tfrac{N-p_1}{N-1}\right)z_1\alpha + p_2\left(\tfrac{N-p_2}{N-1}\right)z_2(1-\alpha)\right\} = \\ &= n^{\Sigma(N)}\Omega^{\Sigma(N)} = \tfrac{n^{\Sigma(N)}\theta^{\Sigma(N)}}{N-1} \end{aligned} \tag{14}$$

Substituting n^P and $n^{\Sigma}$from (11) and (12) in (13) and (14), we get:

$$Y^{P(N)} - Y^{\Sigma(N)} = \frac{M}{N-1}\left[\frac{\Omega^{P(N)}(N-1)\Lambda^{\Sigma(N)} - \theta^{\Sigma(N)}\Lambda^{P(N)}}{\Lambda^{P(N)}\Lambda^{\Sigma(N)}}\right] \tag{15}$$

[5] Polyarchies and hierarchies are compared in Gersbach and Wehrspohn (1998).

Then ,manipulating (15), we have the following:

Proposition 3 *With only two kinds of projects (good and bad) and a budget constraint, a polyarchy dominates a network architecture in terms of expected value of approved projects if and only if:*

$$N > \widetilde{N} = 1 + \frac{\theta^{\Sigma}\Lambda^{P}}{\Omega^{P}\Lambda^{\Sigma}} \tag{16}$$

Proof. Immediate from (14). ■

Proposition 3's insights are consistent with our previous results. With a finite number of decisional nodes and bad initial portfolios, the screening disadvantage of polyarchies is to reject more good projects than networks because of less spread information flows. However, whether N is sufficiently large and in presence of a budget constraint, this negative feature is compensated by stronger *decisional redundancy.* This entails higher average quality and higher expected value of accepted projects.

5 Discussion

In this note we have studied screening efficiency of networks as organizational system by comparing them to polyarchies and hierarchies. Our results point out that polyarchies perform better than network if there are infinitely many decisional nodes and well-endowed intial portfolios. In contrast, networking is a preferable solution for organizations facing well-endowed projects portfolios, but a limited number of decisional units. In this case, many-to-many information flows assure a better performance by reducing decisional redundancy. However, with finite nodes and a budget constraint on acceptable projects, within polyarchies this redundancy assures more accurate screening and better quality approved projects as far as there are sufficiently many decisional units.

Some answers to our starting question - *whence networking ?* - can be drawn. First of all, given good initial portfolios networking is a dominant choice for organizations and systems with a fixed or limited number of members or basic units. By assuming a networked organizational architecture these systems can achieve stronger innovation and implement a larger fraction of good projects. This, for instance, can be the case of research centres or open-source communities where decisions pertain alternative innovations or improvements and these are assumed by few technicians. In opposition, polyarchies are preferable than networks for economic systems, like decentralized markets, where the number of potential decisional units is very large and economic endowments constrain decisions. Finally, hierarchies are here confirmed to be optimal organizational architectures in correspondence to initial portfolios largely composed by bad alternatives and hence high probability of Type II errors.

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