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by Mark Gradstein

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Provision of Public Goods With Incomplete Information: Decentralization vs. Central Planning

Mark Gradstein
Department of Economics
Ben Gurion University
Beer Sheva, Israel

Abstract

This paper compares decentralization and central planning in the context of the provision of public goods with incomplete information on the individual cost of participation. Decentralization is represented by voluntary contributions whereby each individual chooses whether and when to make his contribution. Central planning is represented by a random selection of the prospective contributor. Assuming that the political outcome in an economy is determined by majority voting, it turns out that random planning frequently emerges as the preferable allocation mode, and is especially advantageous in large groups, or when public decision is valuable or urgent.

1. Introduction

Public goods is a typical example of market failure that has served as an argument for government intervention since the writings of John Stuart Mill. Many economists have been quick to recognize the limits of government intervention and the corresponding causes of "intervention failure". Following the insights provided by the public choice literature, it is now commonly agreed that any plausible model of the government should focus on the positive aspects and incorporate real life elements which may be detrimental for government intervention. Indeed, some public goods are provided by private individuals and voluntary organizations (e.g., charity donations) whereas provision of others is usually done by governments (e.g., national defence). One of the factors likely to cause failure of centralized intervention is incomplete information on the part of the central authority; it is reflected in the popular statement that the consumer knows what is best for him better than the government official does.

In this paper, I assume that both decentralization and government intervention involve incomplete information and compare the welfare performance of these allocation methods. I consider a group of individuals contemplating the provision of a public good. The production function of this good is extremely simple: the good is provided if and only if at least one individual contributes towards its provision. At the same time, the contributors incur a cost which is private information. The issue at hand is to efficiently coordinate the individuals' actions. Efficiency here implies that the public good should be provided by the lowest cost individual if and only if that individual's cost is lower than the group's benefit from the public good; otherwise, the public good should not be provided.[1] Decentralization is represented by voluntary contributions whereby each individual chooses, independently of the others, whether and when to make his contribution. The outcome of this game is represented by a symmetric Bayesian-Nash equilibrium.

Central planning is represented in the model by a (probably imperfect) rule which selects the prospective contributor at random. In particular, an implicit assumption hidden in my approach is that for various reasons (transaction costs, for example) the planner is unable to elicit cost information from the individuals. This precludes optimal mechanism design as well as the facility to conduct tests for assessing the individual's personal traits and abilities.[2] Another assumption made implicitly in this paper, which is consistent with most of the public finance literature, is that the planner is benevolent in the sense of faithfully representing the individuals' interests. A more realistic approach would model the planner as one who has vested interests which are remote from those of the public, as is done in the public choice literature.[3]

The results indicate that planning is frequently preferred to decentralization by a vast majority of individuals, which may explain why hierarchical organizational structure characterized by at least some exercize of (possibly incompetent) authority, is so widespread even in democratic societies. According to this paper, such structures are especially advantageous in large groups or when the public decision is valuable. In contrast, decentralization performs relatively better in small groups, for relatively unimportant public decisions. This may explain the prevalence of voluntary forms of organization (e.g., the family unit, agricultural cooperatives, etc.) in small groups. Analysis of the dynamic version of the paper indicates that the urgency of the public decision can also have importance: the more urgent the problem, the more likely is planning to emerge as a viable political outcome. This may help to explain why public decision making tends to become more centralized in emergency situations. Indeed, during both World War I and World War II decentralization was supplanted by government planning as a major coordinating mechanism (see Pigou, 1941, and Devons, 1950, for evidence of this). The scope of the government discretionary decision is widened not only during wartime but during economic crises as well as is evident from the US history during the Great Depression.

This study is related to the work on organization design in which the importance of incomplete information has been recognized – see e.g., Arrow, 1984, Sah, 1991. Ledyard and Palfrey, 1990, provide characterization of efficient mechanisms in a similar but different context and show that under a variety of circumstances random allocation is optimal. Palfrey and Rosenthal, 1988, 1991, consider a model which corresponds to the static version of decentralized decision making of this paper; Bliss and Nalebuff, 1984, and Vega-Redondo, 1990, focus on the dynamic version of the model, but neither author purports to make a welfare comparison that is presented here. This paper is close in spirit to the work of Bolton and Farrell, 1990, which is concerned with a comparison between decentralization and central planning, albeit in a different economic context. A recent study Gradstein, 1992, also contains some preliminary discussion of this issue. The major focus of this contribution as opposed to the previous two is on majority voting as the actual determinant of political outcomes in an economy.

2. Analysis of the static case

A. The model

Consider n individuals who contemplate the provision of a public good. Technology is such that the contribution of a single individual is sufficient in order for the public good be provided. The value of the public good for each individual is a known constant s, $s \in (0,1]$. The private cost associated with individual i's participation in the provision of the public good is c_i.[4] It is assumed that each individual knows his own c_i, but only has incomplete information as to the other individuals' costs. More precisely, from individual i's viewpoint other individuals' costs are independent random variables, each of which is distributed according to the uniform probability distribution function over the unit interval.[5] Each individual's utility is given by the sum total of the value of the public good and the amount of private consumption.[6]

I compare performance of the following two alternative allocation procedures in the simple public decision context given above.

Procedure A. A decentralized procedure in which each individual's strategy is whether or not to contribute as a function of his type. If (and only if) at least one individual volunteers to contribute then the public good is provided, the volunteers incurring the cost of its provision. This yields a game of incomplete information among the individuals. Bayesian-Nash equilibrium constitutes the solution concept for this game.[7]

Procedure B. Imperfect central planning in which allocation is implemented randomly under the veil of ignorance. More precisely, under the second procedure the planner is assumed to implement the allocation, in particular, to nominate the potential contributor randomly such that the probability of each individual to be selected for the task is p/n. Thus, the probability that the public good will be provided is p, where p is chosen by the planner so as to maximize his expected utility.

The main results presented below remain unchanged under different modifications of the above model. One modification is to require contributions of several individuals for the provision of a public good. This version turns out to be less tractable, but yields analogous results. Another, even more interesting modification – analysis of which is presented in the appendix – is to randomly select the contributor(s) in the case of an excessive number of volunteers. Again, the conclusions are similar to those of the simplified version.

B. Utility levels under the two procedures

In this section I derive utility levels obtainable under the two alternative allocation procedures in order to compare their performance.

Procedure A. In this case consider symmetric Bayesian-Nash equilibria of the following type: contribute iff $c_i < c^*$. The cutoff value c^* is given by

$$s - c^* = s - s(1 - c^*)^{n-1} \qquad (1)$$

This value expresses indifference of the boundary individual type, c^*, between the two possible actions. Individual i's utility is then as follows (see also Figure 1):

$$u_i^A = \begin{cases} s - c_i & \text{if } c_i < c^* \\ s - s(1 - c^*)^{n-1} & \text{if } c_i \geq c^* \end{cases} \tag{2}$$

<u>**Insert Figure 1 Here**</u>

Some properties of the equilibrium are summarized below.

<u>Lemma 1</u>

(i) Equilibrium exists, is unique, and is characterized by a cutoff $c^* \geq s/[1 + s(n-1)]$;

(ii) The cutoff point c^* is an increasing function of s and a decreasing function of n;

(iii) c^* tends to 0 as n tends to infinity, or as s tends to 0.

(All the proofs are relegated to the appendix.)

It is worth noting for the subsequent analysis that the equilibrium is inefficient. In particular, it may yield either insufficient or excessive contributions relative to the social optimum.

<u>Procedure B.</u> In this case, it is assumed that the planner acts as the maximizer of the expected utilitarian social welfare function, hence he chooses p in order to maximize $Eu_i^B = E(s - c_i/n)p = (s - 1/2n)p$, where u_i^B is individual i's utility.

The maximizing value of p is 0 if $ns < 1/2$ and 1 otherwise, the interpretation being that the planner provides the public good only if its social value (ns) exceeds its expected cost (1/2). Substituting this back into the individual utility function, I obtain

$$u_i^B = \begin{cases} 0 & \text{if } ns < 1/2 \\ s - c_i/n & \text{if } ns \geq 1/2 \end{cases} \tag{3}$$

Under the assumptions made the above procedure is ex ante individually rational, that is, it ensures each individual non-negative expected utility. In ex post terms, however, the procedure does not guarantee each individual a non-negative utility level. Thus, its implementation hinges on some sort of binding contract between the planner and the individuals which would force the individual chosen to be a contributor to make his contribution.

C. Welfare comparison between the two procedures

From the analysis of the previous section, it follows that the welfare differential between procedures A and B, Δu, is

$$\Delta u = u_i^A - u_i^B = \begin{cases} \text{Max}\,[s - s(1-c^*)^{n-1},\ s - c_i] & \text{if } ns < 1/2 \\ \text{Max}\,[s - s(1-c^*)^{n-1},\ s - c_i] - (s - c_i/n) & \text{if } ns \geq 1/2 \end{cases} \tag{4}$$

It is clear that as long as $ns < 1/2$, decentralization is a superior procedure from the standpoint of every individual since in this case the planner always chooses not to provide the public good. The rest of the paper concentrates, therefore, on the case where $ns \geq 1/2$. The following diagram illustrates the corresponding utility levels u_i^A and u_i^B in this case.

Insert Figure 2 Here

It is clear from the diagram that A is preferred to B only by those individuals for whom $c_i > \tilde{c}$. It is also quite straightforward to calculate the cutoff point making the welfare differential, Δu, equal 0: $\tilde{c} = ns(1 - c^*)^{n-1} = nc^*$, that is, the cutoff point equals the expected number of contributors under the decentralized procedure.

The next proposition deals with the relative attractiveness of the two procedures as a function of the parameters.

Proposition 1. The larger is the population is and the larger is s, the larger is the proportion of individuals who prefer random planning to decentralization. In particular, for sufficiently small values of s, decentralization is almost unanimously preferred to random planning, whereas for sufficiently large values of n, random planning is almost unanimously preferred to decentralization.

The intuition behind the comparative statics result with respect to n is that as n increases, the planner chooses to provide the public good with probability 1 because of its high value to the individuals. Thus, although as n increases it becomes more difficult to nominate the right person as a contributor, the public good will be provided and, indeed, with an increase in population, the social value of this decision increases. On the other hand, decentralization performs poorly in economies with a large population because of the increased likelihood of excessive contributions. Therefore, large populations are favorable for random planning. The intuition behind the result dealing with the change in s is that as s increases, the social value of the public good increases faster than its value for a single individual, hence the more valuable the public good, the better random planning performs relative to decentralization.

Another interesting issue is to compare the utilitarian social welfare functions in the two cases. Graphically, these are given by the corresponding areas under the u_i^A and u_i^B curves in Figure 2, that is,

$$w^A = \int_0^{c^*} (s-c)dc + \int_{c^*}^1 [s - s(1-c^*)^{n-1}]dc = s - c^* + c^{*2}/2 \quad (5)$$

$$w^B = \int_0^1 (s-c/n)dc = s - 1/2n \quad (6)$$

and, therefore,

$$\Delta w = w^A - w^B = [(c^*-1)^2 - 1 + 1/n]/2 \quad (7)$$

which is positive for $c^* < 1 - (1-1/n)^{1/2}$ and negative otherwise. Recalling that $\tilde{c} = nc^*$, it can be seen that from the standpoint of social welfare maximization, decentralization is preferable if and only if $\tilde{c} < n[1 - (1-1/n)^{1/2}]$. Since this allocation mode wins the political support of a majority when $\tilde{c} < 1/2 < n[1 - (1-1/n)^{1/2}]$, it may happen that decentralization, while being socially optimal, is defeated in a political process. Because $n[1 - (1-1/n)^{1/2}]$ tends to 1/2 as n tends to infinity, the likelihood of the majority voting to produce a socially suboptimal outcome is diminished in large populations. Hence, we have the following result:

Lemma 2. The political outcome is not necessarily socially optimal; in particular, whenever $1/2 < \tilde{c} < n[1 - (1-1/n)^{1/2}]$, a majority of individuals prefer a socially inferior mode of random planning. When n is large, this suboptimality becomes unlikely.[8]

As an illustration of the above, consider Table 1 which presents numerical tabulation of the cutoff point $\tilde{c}$ and of Δw for selected values of n and s.

Insert Table 1 Here

Table 1 vividly shows that even for relatively small values of the parameters, random planning performs impressively well. In particular, it is typically the case that a majority of individuals in this example prefer random planning to decentralization.[9]

In an appendix I present analysis of a hybrid between decentralization and random planning which eliminates the problem of excessive contributions. The modified procedure represents some improvement over the pure decentralization studied above. It is important to note, however, that once again, in many cases random planning will constitute the actual political outcome under majority voting.

3. Time dynamics

This section introduces time dynamics into the static model described above. More precisely, it is assumed that decentralization may involve delay, while centralized decision is implemented immediately.[10] For simplicity, individuals are assumed to plan their contribution decisions over a time horizon which consists of only two periods. The nature of the dynamic decentralized procedure (referred to as AD) is such that if the public good is provided during the first period, then no second period contributions are made. Otherwise, individuals may continue to contemplate making contributions. Let x_i^t denote individual i's decision in period t, $x_i^t = 1$ the decision to contribute, and $x_i^t = 0$ the decision to refrain from making a contribution. Furthermore, if at least one of the individuals decides to contribute in period one, then necessarily $x_i^2 = 0$, $i = 1,...,n$ (it is assumed that past actions are perfectly observable). As previously, individuals decide on their actions as a function of their type. In addition, an individual's second period action can be conditioned on the first period actions and each individual's second period beliefs are updated in the Bayesian manner. Individuals act so as to maximize the discounted sum of their utilities, δ, $0 < \delta < 1$ being the common discount rate. The remainder of the model, whose present structure is of the war of attrition type, is exactly as in Section 2. I am interested in the symmetric perfect Bayesian-Nash equilibrium of the resulting game. The following proposition characterizes that equilibrium.

<u>Proposition 2</u>. Equilibrium is characterized by cutoff points (c_1^*, c_2^*), such that if $c_i < c_1^*$, individual i should contribute in period 1; if $c_1^* < c_i < c_2^*$, individual i should contribute in period 2 unless the public good had been provided in period 1; and, finally, if $c_i > c_2^*$, individual i does not have to make a contribution at all. The beliefs in period 2 are a truncation of the first period beliefs.[11]

In equilibrium time then acts as a revelation mechanism by sorting out individuals according to their costs. An explicit characterization of the cutoff points is provided by backwards induction argumentation. The following equation expresses indifference of the boundary type c_2^* between contributing in period 2 and not contributing at all:

$$s - c_2^* = s - s((1 - c_2^*)/(1 - c_1^*))^{n-1} \tag{8}$$

This equation yields c_2^* as a function of c_1^*, more precisely, an increasing function. Then we have an equation which expresses indifference of the boundary type c_1^* between contributing in period 1 and postponing his contribution decision:

$$s - c_1^* = s - s(1 - c_1^*)^{n-1} + \delta(1 - c_1^*)^{n-1} \text{Max}\,[s - c_1^*,\ s - s((1 - c_2^*)/(1 - c_1^*))^{n-1}] \tag{9}$$

From the last equation c_1^* is determined. Taken together, the above two equations fully characterize the equilibrium cutoff points. It can be shown that the solution of (8) and (9), hence equilibrium, exists and is unique. Comparative statics analysis reveals that both cutoff points increase in s and decrease in δ, which implies that both the proportion of the first period contributors and the proportion of the second period contributors increase in the value of the public good and decrease in the discount factor. It may be interesting to compare intuitively the basic procedure A with its dynamic analog AD. An obvious disadvantage of AD relative to A is possible inefficient delay in the provision of the public good. On the other hand AD performs a better selection of the contributing individuals by decreasing the probability of excessive contributions in period 1 (it can be shown that $c_1^* < c^*$). Thus, the more patient individuals are, the more likely AD is to outperform A, and vice versa for impatient individuals.[12]

Assuming that $n = 2$ and $s \geq 1/2$, the expected utility of an individual type c_i under decentralization, u_i^{AD}, is as follows:

$$u_i^{AD} = \begin{cases} s - c_i & \text{if } c_i < c_1^* \\ s - s(1 - c_1^*) + \delta(s - c_i)(1 - c_1^*) & \text{if } c_1^* < c_i < c_2^* \\ s - s(1 - c_1^*) + \delta(1 - c_1^*)(s - c_2^*) & \text{if } c_i > c_2^* \end{cases} \qquad (10)$$

Since, with the assumptions made, the planner chooses to provide the public good, the expected utility of type c_i under central planning, u_i^B, equals $s - c_i/2$. It is not difficult to establish that the welfare comparison between the two allocation methods in this case hinges on a cutoff value c^o, such that an individual prefers random planning if and only if his cost is less than c^o (see Figure 3). Furthermore, it can be shown that this value is an increasing function of s and a decreasing function of δ.

Insert Figure 3 Here

Table 2 provides numerical tabulation of the cutoff point c^o for selected values of the parameters s and δ. This table clearly shows that when individuals are patient enough (that is, when δ is sufficiently large), the majority of individuals prefer decentralization to random planning.

Insert Table 2 Here

This is quite intuitive since when individuals are patient, the delay factor, which is a disadvantage of AD, becomes less important, and we are left with the advantage of producing a better selection of contributing individuals. Naturally, when individuals are impatient, then random planning performs much better (in terms of the proportion of individuals who prefer this procedure) than AD. This suggests that planning is expected to emerge as a viable political outcome in emergency situations where public decisions are urgent, such as during wartime or economic crises.[13]

4. Concluding remarks

This paper attempts to make a further contribution to the debate regarding the comparison between decentralization and intervention in the provision of public goods. The presented model elucidates some of the factors which are significant for this issue. Under conditions of incomplete information, both decentralization and central planning, as they are modelled in this paper, are imperfect resource allocation procedures, and the comparison between the two hinges on the parameters of the model, such as the value of the public decision at stake, the size of the group of individuals, the urgency of the public decision and others. Specificity of the model prevents us from making general conclusions as to the effect of these factors. Casual empiricism, however, supports the view that in many examples of public decision making, some of which are provided in the Introduction, these factors are indeed important.

APPENDIX

Proof of lemma 1. Consider

$$c = s(1-c)^{n-1} \tag{1'}$$

Recall that c varies in the unit interval. Since the left-hand side in (1') increases in c and the right-hand side decreases (both continuously), the intersection between the two exists and is unique. Since $s(1-c)^{n-1} \geq s[1-(n-1)c)]$, it follows that $c^* \geq s/[1+s(n-1)]$.

$$\frac{\partial c^*}{\partial s} = \frac{(1-c^*)^{n-1}}{1+s(n-1)(1-c^*)^{n-2}} > 0, \text{ and } \frac{\partial c^*}{\partial n} = \frac{s(1-c^*)^{n-1}\ln(1-c^*)}{1+s(n-1)(1-c^*)^{n-2}} < 0.$$

As n tends to infinity, or s tends to 0, the right-hand side in (1') -- hence c* -- tends to 0.

Proof of Proposition 1. The proof focuses on the behavior of nc* as the parameters n and s change.

$\frac{\partial(nc^*)}{\partial s} = n\frac{\partial c^*}{\partial s} > 0$. Furthermore, since c* tends to 0 as s diminishes to 0, so does nc*.

$$\frac{\partial(nc^*)}{\partial n} = c^* + n\frac{\partial c^*}{\partial n} = c^* + n\frac{s(1-c^*)^{n-1}\ln(1-c^*)}{1+s(n-1)(1-c^*)^{n-2}} = c^* + n\frac{c^*\ln(1-c^*)}{1+(n-1)c^*/(1-c^*)},$$ the sign of

which is the same as the sign of $(1-2c^*) + n[c^* + (1-c^*)\ln(1-c^*)]$. c* attains its maximum when s=1 and n=2 (see lemma 1), in which case it equals 1/2. The bracketed expression above increases in c* and therefore attains its minimum at c*=0, in which case it equals 0. Hence $(1-2c^*) + n[c^* + (1-c^*)\ln(1-c^*)] > 0$, which proves that nc* increases in n. Since $c^* \geq s/[1+s(n-1)]$ and nc* increases in n, it follows that the limit of nc* is greater than $ns/[1+s(n-1)]$, which can be made arbitrarily close to 1.

A hybrid of decentralization and random planning

In this appendix I briefly consider the following combination of the two procedures considered in section 2 (Procedure H). Suppose that individuals volunteer to make contributions. Then the planner enters the stage by choosing the contributor randomly if and only if there is an excessive number of volunteers (that is, if this number exceeds 1). This modification, therefore, eliminates one of the possible inefficiencies of decentralization, namely, excessive contributions. Once again, we are interested in the equilibrium strategy which is characterized by a cutoff point c** as follows: volunteer if and only if your cost is below c**. If individual i decides to volunteer, then the public good is certainly provided. This individual's expected cost, however, is less than c since he is effectively chosen as a contributor with probability $1/(j+1)$, where j is the number of individuals other than individual i whose cost is below c**. Individual i's expected utility therefore is $s - c_i E(1/(j+1))$, which after some manipulations yields

$$s - c_i [1 - (1 - c^{**})^n]/nc^{**} \tag{11}$$

If individual i decides not to volunteer, then his expected utility is

$$s[1 - (1 - c^{**})^{n-1}] \tag{12}$$

Since the boundary type, c**, should be indifferent between the two actions available to him, we have the following equilibrium condition:

$$s - c^{**}[1 - (1 - c^{**})^n]/nc^{**} = s[1 - (1 - c^{**})^{n-1}] \tag{13}$$

Denote by u_i^H an individual's utility under the modified procedure. The comparative statics analysis of the effects of changes in s and n on c** and u_i^H yields results which are virtually identical to those of lemma 1, and I will not reiterate them. Furthermore, since $s - c_i[1 - (1 - c_i)^n]/nc_i > s - c_i$, it follows that $c^{**} > c^*$ and that $u_i^H \geq u_i^A$ for any $c_i > 0$, that is the modified procedure outperforms pure decentralization.

As in the previous section, when $ns \geq 1/2$ the comparison between modified decentralization and random planning hinges on a cutoff value $\hat{c}$, such that individual i prefers random planning if and only if $c_i < \hat{c}$. This cutoff value is given by the following equation:

$$s - \hat{c}/n = s - s(1 - c^{**})^{n-1} \tag{14}$$

Proposition 1' constitutes an analog of Proposition 1, and its proof proceeds similarly.

Proposition 1'. The proportion of individuals who prefer random planning to modified decentralization is an increasing function of both n and s.

Insert Table 3 Here

Qualitatively, therefore, the results in this case are very similar to those of pure decentralization, quantitatively, however, the results differ. A brief glance at Table 3 will convince the reader that, depending on the parameter values, the modification may significantly improve the performance of the decentralized procedure. Even the modified procedure, however, is usually inferior to random planning from the standpoint of a majority of individuals. It is only for very small values of parameters n and s that the modified procedure is preferred to random planning by a majority. Thus, a combination of decentralization with corrective random planning is more attractive than decentralization alone and sometimes (especially for small groups and for not very valuable public decisions) outperforms random planning. The latter emerges, however, once again, as a potent resource allocation method.

FOOTNOTES

1. Robustness of the results with respect to some of the assumptions is discussed below.

2. Admittedly, viewing the planner as being completely uninformed is inappropriate in many circumstances, however this modelling captures the idea that the planner is frequently required to make decisions when he lacks all adequate information.

3. See Gradstein, 1993, for one attempt in this direction; results obtained under this alternative approach tend to favor the planner less than those obtained in this study.

4. It may be useful to think of contributions in terms of effort (as they are in the case of the military draft, for example), rather than financial contributions.

5. Many of the results remain unchanged for a general probability distribution, so that this assumption is adopted mainly for notational simplicity.

6. Similar variations of this model have been considered in Bliss and Nalebuff, 1984, Palfrey and Rosenthal, 1988, 1991, Vega-Redondo, 1990.

7. See Bolton and Farrell, 1990, for more detailed arguments justifying this approach.

8. Note that even when n is small, the range of values of $\tilde{c}$ for which the political outcome is suboptimal is relatively narrow; for instance, when $n = 2$, this range is $(0.5, 0.6)$.

9. Note that since $c^* \geq s/[1 + s(n-1)]$, $nc^* > 1/2$ (that is, the majority is in favor of the random planning), whenever $n > (1-s)/s$. In particular, this holds true when $ns > 1$, that is, when the planner's decision to provide the public good is socially optimal for all possible configurations of individual costs.

10. Although the model contains many naive assumptions, tradeoffs similar to those indicated below exist in alternative versions as well – see Gradstein, 1992, for an example.

11. The proof is standard and can be derived by writing down the incentive compatibility constraints; see below where the equilibrium is explicitly derived.

12. This is illustrated under simplifying assumptions in the AD case below.

13. As an illustration of this point consider the following account of public intervention in Middle Ages:

"Magistrates were authorized to convoke the army, to lead it into battle, to preside over assemblies of justice, and to carry out the judgments of those assemblies... Inside the borders the power of magistrates was most oppressive and invasive in what is called "dangerous" times (the word *danger* being a derivative of the Latin *dominiura*, denoting a need to exercise greater powers of domination and more strict discipline)."

(Aries and Duby, 1988, p. 10)

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Table 1: Tabulation of $\tilde{c}$ and Δw for selected values of s and n (here and in Tables 2 and 3 bold numbers represent preference for random planning by the majority of individuals).

n	s	.10	.20	.30	.40	.50	.60	.70	.80	.90
2	$\tilde{c}$			.46	**.57**	**.67**	**.75**	**.82**	**.89**	**.95**
	Δw			.05	**.01**	**-.025**	**-.06**	**-.07**	**-.09**	**-.10**
4	$\tilde{c}$		**.52**	**.68**	**.81**	**.92**	**1.00**	**1.00**	**1.00**	**1.00**
	Δw		**+0**	**-.03**	**-.06**	**-.09**	**-.10**	**-.10**	**-.10**	**-.10**
8	$\tilde{c}$	**.51**	**.78**	**.97**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
	Δw	**+0**	**-.02**	**-.03**	**-.05**	**-.05**	**-.05**	**-.05**	**-.05**	**-.05**
16	$\tilde{c}$	**.76**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**
	Δw	**-.05**	**-.03**	**-.03**	**-.03**	**-.03**	**-.03**	**-.03**	**-.03**	**-.03**

Table 2: Tabulation of c° for selected values of δ and s (n=2).

δ	s	.30	.40	.50	.60	.70	.80	.90
.10		.46	**.55**	**.63**	**.71**	**.79**	**.85**	**.91**
.20		.42	**.51**	**.59**	**.67**	**.75**	**.81**	**.87**
.30		.38	.46	**.55**	**.63**	**.70**	**.77**	**.84**
.40		.33	.42	**.51**	**.59**	**.66**	**.73**	**.80**
.50		.29	.38	.46	**.54**	**.62**	**.69**	**.75**
.60		.25	.33	.42	**.50**	**.57**	**.64**	**.71**
.70		.21	.29	.37	.45	**.53**	**.60**	**.67**
.80		.17	.25	.33	.41	.48	**.55**	**.64**
.90		.12	.20	.29	.36	.45	**.54**	**.64**

Table 3: Tabulation of $\hat{c}$ for selected values of s and n.

n	s	.10	.20	.30	.40	.50	.60	.70	.80	.90
2				.43	**.52**	**.62**	**.68**	**.73**	**.75**	**.77**
4			.49	**.60**	**.68**	**.74**	**.78**	**.81**	**.83**	**.85**
8		.46	**.65**	**.74**	**.80**	**.83**	**.86**	**.88**	**.89**	**.91**
16		**.63**	**.78**	**.84**	**.88**	**.90**	**.92**	**.93**	**.94**	**.95**

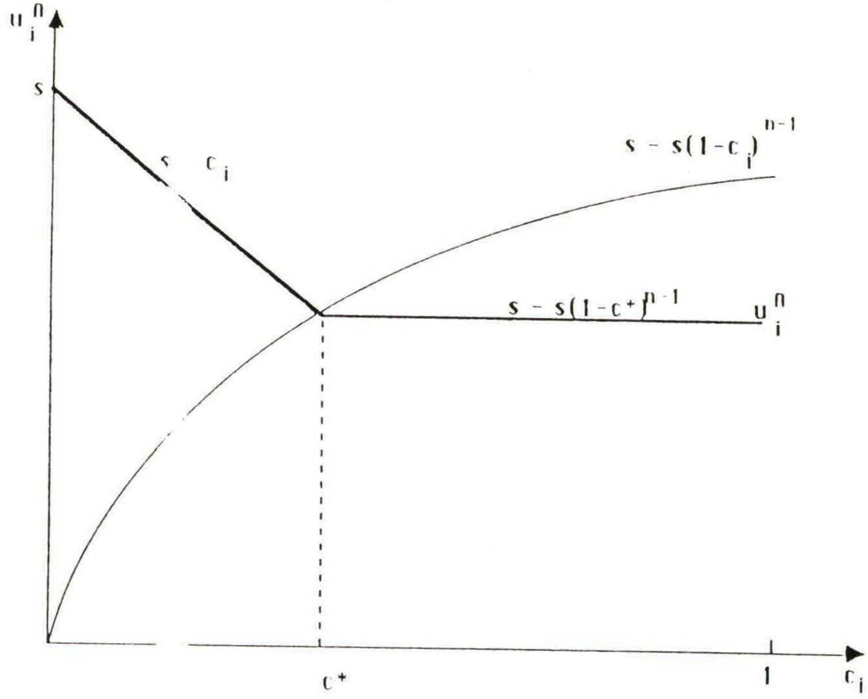

Figure 1: Derivation of u_i^n (bold line)

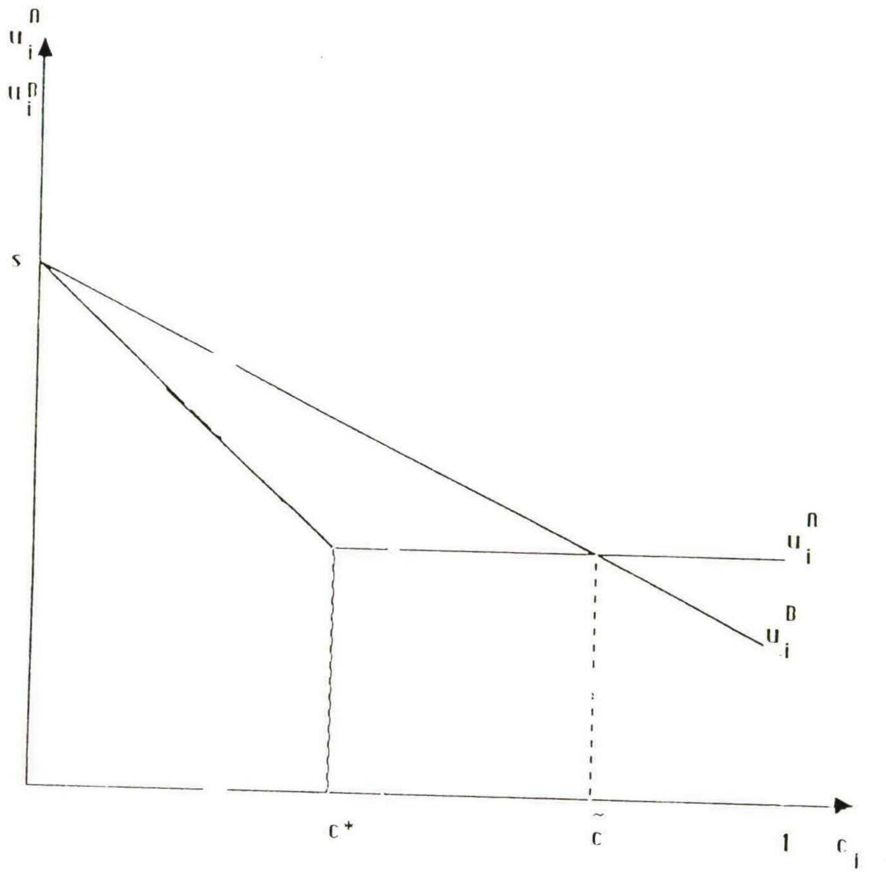

Figure 2: Welfare comparision between decentralization (Procedure A) and random planning (Procedure B) in the static case

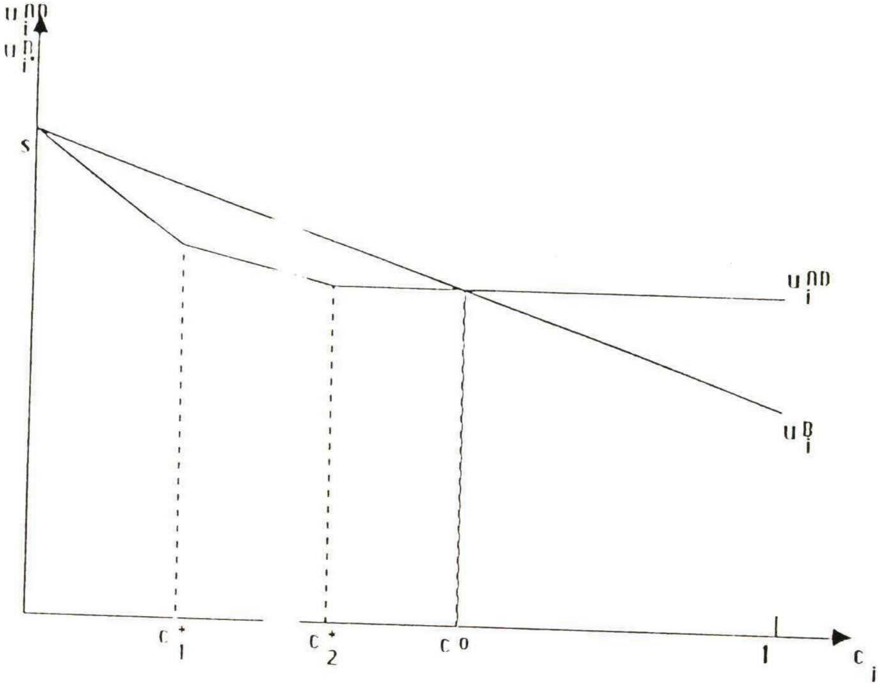

Figure 3: Welfare comparison between decentralization (Procedure A) and central planning (Procedure B) in the dynamic case

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