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## SHORT RUN DECENTRALIZED PROCEDURES FOR PLANNING: A COMPARISON

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## 1 - INTRODUCTION

The theory of economic plannning is a very extensive field which has benefited in the last decades from the development and application of mathematical programming to the problem of allocating scarce resources in societies subject to authoritarian planning. The litarature is vast but instead of surveying all important contributions, we will concentrate in this paper on appraising the role and the desirable properties of decentralization in planning theory and on reviewing and comparing three decentralized procedures for planning in the light of these properties. The first two are price-guided procedures while the third is not, relying on quantity messages, and all procedures are short run. Restricting our attention to the most common approaches to the planning problem will permit us to understand the advantages of decentralization in greater detail. We sill start by examining the structure of the planning problem and the characteristics of descentralization.

## 2 - THE NATURE OF THE PLANNING PROBLEM

A short run decentralized or multi-level planning procedure is an iterative procedure which aims to solve the problem of finding an optimal plan for activity for a centrally planned economy in the near future.

It is relevant mostly for developed economies where planners are concerned with maintaining the efficient day to day running of the economy and is applicable only to economies where the government can, if necessary, give binding directives concerning consumption and production plans to all consumers and producers in the economy. In these command economies, the programming of government activities requires that policy makers seek to achieve certain goals while limited by external constraints in their range of possible actions.

Planning is viewed here as a contrained maximization of some target function of variables regarded as social objectives: the objective function subject to imposed constraints.

In the task of approaching the planning of an economy as a constrained maximization problem, the first step is to identify the "choice variables" - the variabels whose levels the planning authority is responsible for choosing, and upon which the success of the plan depends. These variables are embodied in the state of the economy which can be determined in detail by the planning authority by choosing a value for every economically important and controlable variable[Heal 1973].

The State of the economy is represented by a vector x whose components are the amount of each input used, and of output produced by each firm. The values assumed by the components of x may be restricted to be non-negative and depend on the contraints imposed by, say, limited resource endowment, technology etc. When x satisfies all constraints it is said to





be feasible.

The set x of all feasible states of economy may be taken as an economy-wide production possibility set, since it depends on the endowments and on the technology of the economy.

The problem faced by the planning authority involves choosing the $x \varepsilon X$ which gives the highest posible value to an objective function u(x). This objective function represents social preferences between alternative states of the economy, indicating to the planning authority how desirable a state of the economy is. These preferences are depicted by a set of smooth non-intersectiong social indifference curves (defined so as to satisfy the requirements of completeness, transitivity and continuity[(1)]) which make is possible to establish a weak order on the alternative states. Thus, finding the feasible state of the economy which gives the highest value of the objective function (being, in general, of ordinal significance only) is equivalent to finding the most preferred of the feasible states.

There are alternative approaches suggesting that the planning procedure should not be viewed as the maximization of an objective function, but rather in the form of a set of targets to be attained. As exposed by Kornai (1967) planners may choose target values for the variables which they consider important

(1) The concepts relevant to the specification of an objective function and to the study of social preferences will not be revised here. We refer to the welfare theory presented in Malinvaud(1972).

and then attempt to find the feasible plan which is some sense conforms best to these targets. Although subject to several limitations this approach is often adopted in practice,possibly due to the difficulties encountered in constructing an objective function. It can, however, be seen as a reformulation of the constrained maximization approach, since a constrained maximization problem has to be solved if feasible and efficient plans are to be found.

Having examined the nature of the objective function to be maximized in the planning procedure we now turn to the nature of the constraints which restrict the set of possible states of the economy.

These constraints may be of two kinds: resource constraints and technological constraints. The former are due to the fact that the supply of inputs available to an economy is limited, in the short run, by exogenous factores beyond the control of planners. The latter refer to technological conditions determining and limiting the production process by specifying the relationship between the imputs and outputs of that process. These conditions are certainly not fixed over time, but are dependent on the rate of technical progress.

Over a long enough time period the two types of contraints can be varied within certain limits, and can be affected by the nature of the economic program adopted.(2) In

(2) Kerens(1972) argues that, even in the short-run these constraints are not exogenous, but can be relaxed by a greater supply of effort or initiative of the entrepreneurs.



short run plans however these constraints are exogenously determined.

## 3 - CHARACTERISTICS OF THE DECENTRALIZED PLANNING PROCEDURE

Since we will be concerned in this paper with decentralized procedures for constructing short run plans,before describing the characteristics of decentralization, we will start by examining the meaning of the short run in the planning context.

The traditional definition of short run is that of a period in which the capital stock is fixed, or, in which the resource constraints cannot be altered. In practice such a period is ussualy of five years, since it generally takes at least this amount of time for projecting, creating and adopting new technologies.

An alternative definition of short run can be given in terms of plans that provide a rather complete description of production and distribution. The longer the period considered, the more difficult it is in practice to construct a detailed plan. The short-run is thus said to be the period (usually up to five years) in which this detailed plan is feasible.

Before assessing the planning procedure as a constrained maximization problem, the conditions under which such a problem may be solved have to be established. The first point to note is that any procedure for solving a large maximization problem has to be an iterative process in which the solution is found by taking sucessive approximations leading to sucessibely improved solutions. More specifically, this method - a routine or algorithm - generally takes the following form: initially an arbitrary plan is proposed and certain indices associated with it are calculated. Some modifications are then made in the light of these indices, and from this, the next proposed plan is derived. The same indices are again calculated, and so on.

The reason for using such an approach is the large size of the problem facing the planning authority,involving too many equations and too many unknowns to be solved at once, and giving rise to the following difficulties:

1. It becomes virtually impossible to concentrate in the Central Planning Bureau all the information required to formalize the planning problem. Also, the transmission of the relevant information from numerous sources to the CPB (from here on the Central Planning Bureau will be called CPB)would induce many kinds of error.

2. Even if it were possible to gather all the pertinent information in the CPB, it would be a formidable task to integrate and process it, as Von Hayek (1945) emphasizes.

These difficulties bring the need for breaking down the planning problem into a number of independent operations



of manageable size to be performed by different agencies. This characterizes the so-called decentralized procedure for planning discussed by Von Hayek (1945) and Malinvaud (1967). The main feature of such a procedure is that all the information available to the CPB and to individual firms is never pooled together in one place.

As an illustration of the informational decentralization process we might say that the CPB has information about the nature of the objective function and about the economy wide constraints. The CPB also has the task of ensuring that overall accounting constraints are satisfied. It delegates to the individual firms the responsibility of satisfying these constraints since they have information only abour their own processes in which these constraints are embodied.

What is essential in the decentralized procedure is that the over-all planning problem is broken into a number os sub-problems each relating to and delegated to the subsectors of the economy. We note also that during the process of calculating a plan both the CPB and the individual firms play an equally important role in the transmission of information and in the calculation of the plan.

## 4 - DESIRABLE PROPERTIES OF A DECENTRALIZED PLANNING PROCEDURE

Several desirable properties have been mentioned in the literature for characterizing a decentralized procedure:

- It is generally expected that the message transmitted by a firm at any stage can depend only on the production possibilities of than firm (or,analogously,on consumption possibilities and preferences of consumers, if it is the case). and on information received in early stages. Also the message transmitted by a firm is supposed to concern only the proposed actions of that firm (consumers). This property has been referred to as the property of <u>informational privacy</u>.

- Another desirable property which is known as the <u>anonimity requirement</u> states that the agents need not know the sources of the information that they receive.

We note that the above properties are of little normative significance, inasmuch as in assessing the value of a planning process it is more important to verify if the amount of information transmitted was minimized (since it introduces costs, delays and errors) even if it conflicts with the above properties. It has been observed in practice, however, that on the whole non-satisfaction of any of them will increase the amount of information to be handled.

- <u>Monotonicity</u>, another property whose importance was stressed by Malinvaud(1967), is said to exist if the value of the objective function increases from one stage to the next (or remains the same in case the solution to the constrained maximization problem has been found, and the plan which



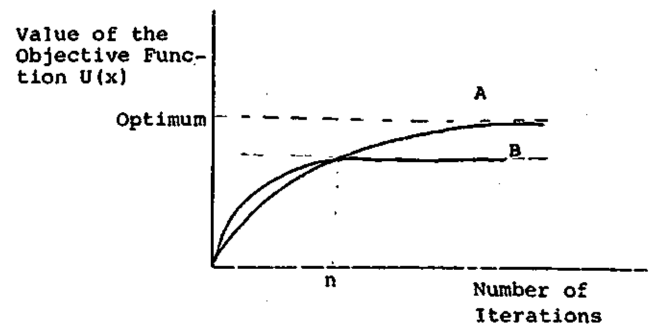
constitutes the solution is as optimum).

- The <u>feasibility</u> property requires that every plan proposed during the iterative process be feasible.

These last to properties are very important because they guarantee that whenever the iterative procedure is terminated, the last step is both feasible and better than the previous steps.

It is also desirable that the planning problem converges to an optimum as the iterations are repeated sufficiently many times. <u>Convergence</u> is, however, an assymptotic property of little practical use since the iterations will be carried out only a finite number of times. It is therefore the result obtained after a finite number of steps that really matters.

As can be seen in the diagram below, both procedures A and B satisfy the monotomicity property byt A converges to an optimum and B does not. In this case, if less than n iterations will be carried out, procedure B should be chosen over A since it yields a higher level of the objective function.



Finally, it is desirable that the planning procedure performs satisfactorily in as many diverse environments as possible; in particular it should function for as many types of economies as possible. The importance of this comes from the fact that it is always necessary to make some assumption about the technology of the economy to be planned, and the procedure to be chosen should fit the reality as closely as possible.

In regard to the costs of different procedures considered institutionally feasible, lowest cost is not considered a criterion for choice because the rules to be followed by firms must be simple, to avoid the risk of being incorrectly followed.

## 5 - REVIEW OF PLANNING PROCEDURES

In what follows we will examine three procedures for calculating short run economic plans. The first is a clear imitation of the market mechanism and the second embodies at least some of its features. Both are price guided procedures which rely on some form of convexity assumptions and therefore do not perform satisfactorily in the presence of production functions subject to increasing returns to scale. The third process circumvents this limitation and differs quite radically from the first two: It makes no use of prices, but of quantitative targets, and operates in the presence of increasing returns to scale.



### 5.1 - Review of Two Price Guided Procedures

The theory of economic planning has been benefiting from the efforts of the so-called economic theory of socialism towards characterizing an optimal plan. Such characterization was made precise as a result of the progress made in the theory of resources allocation,[4] and it has been shown in the literature that an optimal plan in the socialist economy should satisfy the same marginal conditions held in equilibrium under perfect competition.

More explicit discussions of the process of plan formation are found in Lange (1936), Taylor (1929), and Kantorovich (1959), who have based their analyses on the Walrasian concept of tâtonnement. Lange's propositions have been formalized in a very thorough study by Arrow and Hurwicz (1960), while Taylor's have been formalized by Malinvaud(1967). The Arrow-Hurwicz and the Malinvaud procedures for planning will be reviewed in the following pages.

#### 5.1.1 The Arrow-Hurwicz Procedure

This approach consists basically in following the Walrasian tâtonnement, a process by which a competitive economy may reach the equilibrium. The objective of the process is to locate an equilibrium price vector; that is, a set of prices that will clear the market.

(4) Koopman's(1957), first chapter, constitutes an excellent review on the subject.

According to this process, all buyers and sellers are gathered together in the presence of an auctioneer who quotes the price for each good and service. The buyers and sellers then state tentatively how much they are willing to buy and sell, respectively,at the given prices. The auctioneer then revises the prices raising the prices of goods in excess demand and lowering those of goods in excess supply. Trade will not occur until an equilibrium price vector equating supply and demand is found. The success of the tâtonnement in locating a market-clearing price vector depends on the assumption of gross substitutability being satisfied, i.e., that when the price of a good rises, the demand for every other good must rise, ruling out the existence of complementarity between any goods.

The Arrow-Hurwicz planning procedure is related to a tâtonnement in the following way: firms are given a vector of prices by the CPB and then they calculate the production programs which would maximize profits and inform the CPB of the supplies, corresponding to those prices. The CPB then distributes the profits among consumers who, facing given profit shares and wage rates, choose their consumption bundles and inform the CPB, which acting as an auctioneer, raises the prices of goods in excess demand and conversely lowers prices if there is excess supply. The process continues until the set of production and consumption bundles converge (if so) to an equilibrium between supply and demand.



Although we have assumed so far that the planning procedure should specify both the output of the productive sector and the distribution of the output among consumers, the large number of consumers makes this last goal impractical. Due to this, the planning literature usually aims to characterize in detail only the productive sector of the economy, assuming the requirements and preferences of consumers to be reflected in the objective function.

Given that the tâtonnement-like process applies only to the productive sector in the plan implementation, the prices announced by the CPB can be interpreted as purely bookkeeping prices. Once the equilibrium price vector is attained firms are required to implement the production programs (complete specification of their inputs and outputs) that maximized profits at these prices. The government then chooses a manner to distribute the resulting outputs of consumption goods among consumers. We note that besides taking the place of consumers at the auction, the CPB also determines the amount of labor that individuals ought to supply (since labor figures among the inputs specified by the firms). The CPB thus acts like a modified auctioneer, since it represents the preferences of individuals between consumption goods and also between work and leisure. Finally, it is assumed that all agents (CPB, firms and indivuals) are guided in their actions by an objective function representing social preferences.

The Arrow-Hurwicz planning procedure is formalized in the following way: The aim fo the procedure is to find a state of the economy which maximizes the objective function:

$$MAX[U(x_i) - \sum_{i=1}^{n} p_i x_i]$$

subject to the production and resource constraints,

$$z_i = x_i - \sum_{k=1}^{m} Y_{ik}$$

$z_i \leq w_i$ (if $z_i - w_i > 0$ there is excess demand; if $z_i - x_i < 0$, excess supply);

where:

$p_i^s$ = price of good i at stage s; i = 1,...,n;

$y_{ik}^s$ = proposed output of good i by firm k at stage s; i = 1,...,n; k = 1,...,m; (It is positive if firm k does in fact produce good i and negative if it uses good i as an input).

$x_k^s$ = proposed final consumption of good i at stage s; i = 1,...,n;

$w_i$ = initial amount of resources available to the economy for food i; i = 1,...,n;

$z_i^s$ = net demand for good i by consumers and firms at stage s; i = 1,...,n.

$U(x_i)$ = utility function, which is assumed continuous and concave which implies that indifference surfaces are convex to the origin.



Observe that in the objective function $[U(x_i) - \sum_{i=1}^{n} p_i x_i]$, U has to have at least a cardinal meaning since an arbitrary monotonic increasing transformation of U could determine a differente optimum.

The vector of final consumption $x_i$ should be feasible from the consumers' point of view and the vector $y_k$ should represent a transformation of inputs into outputs which is technically feasible. For simplicity, these constraints are expressed by saying that these vectors belong to sets given a priori, that is: $x \in X$ and $y_k \in Y_K$.

The procedure starts with the CPB issuing a arbitrary price vector $p^{s-1}$ at stage s-1. At this same stage, firm k responds by proposing to supply a certain amount of output, which maximizes its profits, given its technical restrictions. By definition (Malinvaud 1967) this means max $\sum_{i=1}^{n} p_i^{s-1} y_{ik}$ over the set $Y_K$, which characterizes the technology available to firm k. The CPB would then revise the price vector $p^{s-1}$ proposed previously, increasing the price of goods for which the proposed net demand exceeds available resources, and reducing it in the opposite case. In order to do so, the CPB calculates the consumption to be budgeted for at stage s-1, determining the vector $x^{s-1}$. The objective of the CPB is to maximize the amount by which utility exceeds the value of consumption:

$$MAX[U(x_i) - \sum_{i=1}^{n} p_i^{s-1} x_i].$$

If $z_i^{s-1} - w_i > 0$, the CPB will increase $p^{s-1}$, and decrease it,if $z_i^{s-1} - w_i < 0$. This price change will be proportional to be excess demand or supply:

$$p_i^s = MAX[0, p_i^{s-1} + \rho (z_i^{s-1} - w_i)],$$

where $\rho$ is a fixed positive coefficient of proportionality and the zero is used as a price whenever the value of $p_i^s$ is found to be negative, which is clearly impossible.

When this new set of prices is determined, the procedure starts all over again until $z_i - w_i < |\zeta|$ where $\zeta$ is a sufficiently small number. When this state s+j is achieved the firms will be required to produce $(y^{s+j} = y^{s+j-1})$ in accordance with prices $p^{s+j}$ and consumption would be determined by the vector of final availabilities $w + \Sigma y_k^{x+j}$. Perhaps, more generally the vector $x^{s+j}$ would be such as to maximize U(x) under the conditions $x \epsilon X$ and $x \leq w + \sum_{k=1}^{m} y_k^{s+j}$. This assertion derives from the fact that at equilibrium the prices $p^{s+j}$ can be interpreted as shadow prices.

To avoid the possibility that firm k finds it impossible to obey the rules of the CPB, if no vector $y_k^s$ maximized profits in the set $y_k$, it is necessary to assume that this set is closed, convex and bounded. The former assumption implies that the limit vector of a convergent sequence of technically feasible vectors is also technically feasible ruling out indivisibilities. The two last ones eliminate cases in which the technology is



represented by a production function subject to increasing returns to scale.

To assure that the final consumption vector will satisfy the condition

$$x \leq w + \sum_{k=1}^{m} y_k^s$$

the set X to which x belongs is assumed closed and convex,and therefore ruling out indivisibilities of consumption.

Given these assumptions, Arrow and Hurwicz's results imply that if the planning procedure is followed and indefinitely increasing number of stages s+j, the price vector converges to a $\bar{p}$ associated with an optimum program. These results however do not imply monotonic convergence.

### 5.1.2 - The Leontief-Samuelson-Malinvaud Procedure

We have seen that the Arrow-Hurwicz Procedure attempts to recreate in a planned economy setting, the results usually achieved through perfect competition. On the supply side firms maximize profits, and on the demand side utility is maximized (assuming the existence of a social utility function instead of individual ones).

Within that formulation, there was no need for the CPB to worry about efficient technologies or input-output coefficients, since the mechanism similar to that of a free entreprise was supposed to take care of this.

In the Leontief-Samuelson-Malinvaud Procedure an attempt is made by the CPB towards representing the technology used by the firms: It builds a model embodying the equilibrium constraints on supply and demand and the technical constraints characteristic of each industry. This procedure is of greater practicability, since in countries where some planning of production takes place, the Central Agency generally purports to represent the technologies employed by firms.

In the Leontief-Samuelson-Malinvaud (L.S.M., for short) Procedure, the CPB uses a Leontief model to represent these technologies, but it allows for variable input-output coefficients avoiding the major weakness in the original Leontief(1951)model.

The basic idea for this procedure is due to Taylor's proposal (1929) of an iterative method by which the CBP informs firms of the prices proposed for their products while they report the technical coefficients which minimize their costs. The CPB then revises its proposed prices in such a way that the price of each good be exactly equal to the costs implied by the technical coefficients proposed by the firms. The price of each input is then adjusted downward or upward(through a tâtonnement process) depending on whether the CPB forecasts a surplus or deficit of the resource in question, by comparison with projected availabilities.



Samuelson's contribution to this procedure is found in his the model(1951) where he relaxed the assumption of fixed technical coefficients. He assumes that there exists only one input (labor) which is available in a fixed quantity and that each firm produces only one good.

The notation that we use in presenting the L.S.M. Procedure is as follows:(5)

$y_{jj}$ = output of firm $j(j = 1,\ldots,\ell-1)$;

$-y_{hj}$ = input h of firm j for $h \neq j$ $(h,j = 1 \ldots, \ell-1)$;

$g_j$ = output $y_{jj}$ of the good j;

$g$ = $(\ell-1)$ vector of $g_j$'s;

$a_{hj} = \frac{-y_{jh}}{y_{hh}}, h \neq j$ = technical coefficient of the input h in the production of j; by convention $a_{jj}$ is zero;

$a_j$ = $\ell$-vector corresponding to the $j^{th}$ firm's technical coefficients (restricted to be non-negative);

$A$ = square matrix of order $\ell-1$ consisting of the $a_{hj}$ relating the goods produced $(h,j = 1,\ldots,\ell-1)$ (Leontief Matrix);

$w_h$ = quantity of good h available;

$f$ = $(\ell-1)$-vector consisting of the technical coefficients relating to the primary factor (labor) where $f_j = a_{\ell j}$;

$w_\ell$ = fixed amount of labor available;

(5) This notation is the same as in Malinvaud (1972) pp.117-123.

$x_h$ = global consumption of commodity h;h=1;...,$\ell$-1 (restricted to be non-negative);

$p_h$ = price of good h (considering the primary factor as a numeraire);

There are $\ell$-1 firms and each specializes in the production of a single commodity, under constant returns to scale. The last commodity is the only factor of production (labor) which is assumed non-consumable and available in a fixed quantity. For each of the other commodities h it is assumed that the quantity of good h($w_h$) equals zero. Finally, there is an utility function $u(x_1, \ldots, x_{\ell-1})$ where the arguments are the global consumptions $x_h$. This is equivalent to assuming that the CPB knows the collective demand functions and can represent them by an objective function U(x) to be maximized.

The constraints are the equality conditions for supply and demand:

$$x_h + \sum_{j=1}^{\ell-1} a_{nj} g_h = g_h, \ h=1,\ldots,\ell-1; \text{ and}$$

$$\sum_{j=1}^{\ell-1} f_j g_j = w_\ell \text{ or, in matriz notation:}$$

$$x + A_g = g' \quad \text{ or } x = (I - A)g \text{ (The Leontief Model) and}$$

$$f'g = w_\ell .$$





The procedure starts with the CPB issuing a vector of price ratios $p_h^s$ of the different commodities (taking the primary factor as a numéraire).

At this stage s the $j^{th}$ firm determines $a_j^s$ so as to minimize its unit cost of production calculated at the prices $p_h^s$, that is $a_j^s$ that minimizes

$$\sum_{j=1}^{\ell-1} p_h^s a_{hj} + f_j$$

in the set of technical constraints $A_j$.

The CPB, after being informed of the vectors $a_j^s$ by each firm, constructs a matrix $A^s$ and a vector $f^s$, and reasons on the basis of the corresponding Leontief model as if these vectors were completely fixed by technical exigences.

The aim of the CPB is then to maximize U(x) subject to the constraints $x = (I - A^s)$ and $[f^s]'g = w_\ell$ (embodying the equality conditions of suply and demand) and it is assumed that the Lagrange multiplier in the last constraint is not zero in the optimum.

The CPB then solves $p'(I - A^s) = [f^s]'$ to compute a new set of prices $p^{s+1}$ and determines x so as to maximize U(x) subject to the constraint $p'x = w_\ell$ (which embodies the two above constraints plus the linear system solved to compute the new set or prices). Finally, the CPB finds the corresponding vector g by solving $x = (I - A^s)g$.

The prices $p_h^{s+1}$ are again issued to the firms and the process continues.

At the final stage s+n, the CPB determines the plan $(x^{s+n}, g^{s+n})$ by calculating first the vector $p^{s+n}$ as above, then by calculating $x^{s+n}$ so as to maximize U(x) subject to the constraint $p^{(s+n)'} x = w_\ell$, and last of all by finding $g^{s+n} = (I - A^{s+n-1})g$.

Now let's summarize the properties of this procedure (an extensive discussion of them is found in Malinvaud 1967): it satisfies the monotonicity criteria since the plan's utility cannot be reduced by the addition of a further stage to the planing procedure. The feasibility and convergence properties are also satisfied since each intermediate plan is feasible and the process leads to an optimal consumption vector,given that U(s) is a strictly increasing function.

We note that this procedure involves a "decomposition" of the total problem of maximizing U(x) subject to the constraints, wich is similar to the "decomposition" method developed by Dantzig and Wolfe(1960).

Another interesting feature of this procedure is that at each state the CPB learns more and more about the technology of each firm, being able to characterize more exactly their production possibility sets.



### 5.1.3 - Comparaison of the Arrow-Hurwicz and the Malinvaud Procedures

Before passing to the non-price guided procedure, we will compare the characteristics of the two procedures just reviewed.

It is easily seen that the Arrow-Hurwicz Procedure is decentralized, as it draws upon the functioning of the market mechanism and satisfies most desirable properties of decentralization. Each firm is assumed to have information only about its own production possibilities. Each agent's message at any stage concerned only its own proposed actions at that step. The property requiring that the source of the message received by each agent was not konwn is not relevant to the firms since the messages which they receive - prices - could only come from one source: the CPB. In what concerns the CPB, the anonimity property is satisfied, since it needs to know only the total demand and total supply of a good,the way in which each firm contributes to these totals being of no relevance.

In contrast the L.S.M. procedure fails to satisfy the anonimity property, because at each stage the CPB receives technical coefficients which permit it to build up approximations to the production possibilities of each firm.

For this purpose, the sources of information are important and not only total amounts. We note also that the recipients of information are differentiated in the L.S.M. procedure since the CPB locates an optimum and informs the firms of the production programs required of them. It is clear that the L.S.M. procedure requires a larger amount of information to be handled, and as the number of firms is increased so are the information-handling costs imposed on the center.

This brings to mind the issue of the optimal size of the firms. For both procedures an increase in the number of firms and a reduction in their sizes brings advantages in terms of greater administrative flexibility within firms. In view of this, the optimun number of firms under a planning system might be defined in terms of the trade-off between administrative costs at the CPB against administrative cost at the firms. In other words, this number is such that the advantages to the CPB of a small reduction in the number of firms are just balanced by the disadvantages of decreased administrative flexibility within the individual firms resulting from the consequent increase in their sizes.

This optimum number of firms will clearly be different for the two procedures. It wi[illegible] larger for the Arrow-Hurwicz procedure, since the costs at the center being unaffected by the number of firms, the optimum size of firms will depend only on the balance of economies and diseconomies of administrative scale



within each firm. In the L.S.M. procedure, however, there will be an incentive to increase the size of firms and reduce their number in order to reduce the costs at the CPB, even if this will create internal planning problems within the firms.

One further difference between the two procedures has to do with the nature of the operations performed by the CPB in each of them. In the Arrow-Hurwicz the CPB is merely required to adjust prices proportionally to the excess supply or demand. In the L.S.M. procedure the CPB performs a more complex operation: It has to solve a constrained maximization problem at each step.

With respect to the monotonicity and feasibility properties the L.S.M. procedure seems to be in advantage. The reasoning here is that the Arrow-Hurwicz procedure does not satisfy the feasibility criterion: At any stage other than the optimum, supply and demand need not be equal. Therefore, except at the optimum the value of the objective function does not reflect the social value of the program. On the other hand, the L.S.M. procedure satisfies both properties, and in case the planning procedure is stopped short of optimality, we can be sure that the last program is at least as good as any of the previous ones.

With respect to the assumptotic convergence properties, the L.S.M. procedure is also superior, since it converges to an optimum. We know however that assumptotic properties are not of much relevance for practical application, since only a small number of stages will be performed. Nonetheless, Heal (1973) mentions that in simulated experiments the L.S.M. procedure has exibited faster convergence.

## 5.2 - Non Price-Guided Procedure

In constrast with the two procedures above, where the information flows take the form of prices, in this third one the propositions of the CPB take the form of allocations of inputs among firms. This seems to show greater similarity to what happens in practice, as has been found that in general actual planning bureaux communicate with the firms by informing them of input allocations, output targets, or both (Montias 1959).

Besides a possible move towards reconciling theory and practice this procedure has a further advantage: It can be shown to perform satisfactorily in the presence of non-convexities of production frontiers. We saw that the previous procedures are heavily dependent on the assumption of convex production possibility sets. In view of the undoubted existence of economies of scale in the real world (Pratten 1965) the need of a procedure dealing with non-convexities is indisputable.

The properties of non-price guided planning procedures have been investigated by J. Kornai and T. Liptak(1963),



J. Kornai(1967) and Heal (1969 and 1973). This last author noted the possibility of using production targets with non-convex production possibility sets. We will review in the following pages the procedure that he developed and which will be called hereafter the Heal procedure.

Instead of quoting prices, in the Heal procedure the CPB proposes, at each stage, an allocation of inputs among the firms. These respond by informing the CPB of the outputs that these inputs would make possible and of the marginal productivities of the inputs at this allocation. Possessing this information the CPB is enabled to assess the marginal contribution to social welfare of each input in each of its uses. Knowing these marginal social values, the CPB calculates a new plan in which by comparison with the first, inputs are moved from uses where their marginal social values are low to those where they are high. In other words a new allocation is proposed, in which by comparison with the previous one, resources have been shifted to uses where they are most marginally productive, and away from those where their marginal contribution is least, each step leading to an incrase in the value of the objectice function representing social welfare.

The following notation is employed in the Heal procedure:

$Y_i$ = amount of good i, i=1, ..., n, produced by firm i;

$x_{ji}$ = amount of resource j, j=1, ..., m, allocated to firm i;

$y_{Ki}$ = amount of produced good K allocated to firm i;

$y_{Kc}=y_{1c},\ldots,y_{nc}$ = amount of produced good K allocated to final demand;

$R_j$ = amount of resource j exogenously available to the economy;

$U(y_{1c},\ldots,y_{nc})$ = social welfare function.

There are n firms indexed by i=1, ...,n and each firm i produces only one output, good i, in amount $Y_i$, according to the equation:

$$Y_i = f_i(x_{1i}, \ldots, x_{mi}; y_{1i}, \ldots, y_{ni}) = (f_i(x_i, y_i).$$

The production functions $f_i$ are assumed to be continuous and differentiable(6) everywhere on the set of feasible allocations, having finite first partial derivaties (marginal productivities) everywhere on this set. From this it follows that if the inputs available to a firm are bounded, so are the outputs that it can produce.

The objective of the planning procedure is to maximize $u(y_{1c}, \ldots, y_{nc})$ subject to the input availability constraints:

$$\sum_{K=1}^{n,c} Y_{iK} \le f_i(x_i,y_i),\ i=1,\ldots,n$$

(6) Note that this procedure, in contrast with the precious ones, makes explicit reference to the nature of the production functions. This is necessary because one of its objectives is to relax the seemingly unnatural assumption of non-increasing returns to scale. This assumption was made in the previous procedures in order to assure convexity of the production possibility sets.



$$\sum_{i=1}^{n} x_{ij} \le R_j,\ j=1,\ \ldots,m.$$

$Y_{iK} \ge 0;\ x_{ij} \ge 0$, for all i, j and K.

To find the solution to this problem, the CPB increases the allocation of a good to uses where its marginal social value is high and vice versa. Such allocation of a good to a use is adjusted by an amount proportional to the difference between its marginal social value in that use and the average of its marginal social values in all uses. This simple idea, however, becomes complicated due to the fact that it could cause violation of the non-negativity constraints.

To avoid this situation Heal has devised a way of implementing this idea without violating the non-negativity contraints. The details of this method however are more involved and we find no point in reviewing it here.(7) Another reason for an increased complexity in the calculations performed by the CPB is due to the fact that when it changes the allocation of inputs to a production process, the output of the process also changes. The CPB is thus faced with the problem of allocating a changing amount of intermediate goods. This also complicates the form of the reallocation equations.

It is proved in Heal (1969) that given that the initial allocation was feasible, the feasibility and non-negativity

(7) For these details see Heal (1969) and (1973), Chapter 7.

constraints will be satisfied during the process. He also proves that the re-allocation process leads to an optimum at the limit point, and that on the path by which these limit points are approached, the objective function increases monotonically. Thus, given that the initial allocation was feasible, monotonicity, feasibility and convergence to an optimum are established for the subsequent states.

## 6 - COMPARISON OF THE THREE PLANNING PROCEDURES

In this section we attempt to compare the three procedures reviewed. Such a comparision is very difficult since as we saw, these procedures differ along many dimensions. Therefore, it seems necessary to restrict our attention to a few important features.

In particular, we will be interested in comparing:

1. Information requirements,
2. Computational tasks,
3. Assumptions about the nature of the economy,
4. Convergence properties.

Even though these aspects are well distinguish. each procedure it seems difficult to compare them independ The reason for this is that advantage in one aspect implies disadvantages is others. For example, more liberal assumptions about the nature of the economy are associated with a greater



informational requirement and more complex computations.

With respect to information requirements, we distinguish the information flows from the firms to the CPB and vice versa. The first thing to notice is that since the so-called anonimity property is observed in the Arrow-Hurwicz much less information is required in this procedure than in the others. The only flows of information are:

a) From the CPB to the firms - prices for each good.

b) From the firms to the CPB:
   - For each product, the total output to be produced by all firms;
   - For each good, the total demand by all firms.

The comparison of the L.S.M. and the Heal procedure is not easy because the anonimity property does not hold, i.e., the CPB has to distinguish the source of each piece of information received. Here it is assumed that each firm produces only one product and no two firms produce the same product.

In the L.S.M. procedure, the flows of information are:

a) From the CPB to firms: prices of the different products.

b) From the firms to the CPB : vector of technical coefficients for each product (firm).

While, for the Heal procedure these flows are:

a) From the CPB to firms: quantities to be produced of the different products.

b) From the firms to CPB: output and marginal productivity of inputs.

With respect to item a), information flowing from the CPB to firms, all procedures seen to be equivalent in quantitative terms. With respect to item b), the Arrow-Hurwicz procedure is in clear advantage,and the Heal procedure seems to be at a light disadvantage in relation to the L.S.M. While in the L.S.M. procedure the firms have to inform only the technical coefficients, in the Heal procedure, besides the marginal productivities they also have to inform the quantities to be produces.

The next point of comparison is the computational tasks of the agents in each procedure, which are summarized below.

In the Arrow-Hurwicz, the computational tasks are:

1. For the CPB:

   - Maximize the amount by which utility exceeds the value of consumption;
   - Change prices proportionally to excess demands.

2. For the firms: Maximize profits at given prices.

In the L.S.M. procedure the tasks are:

1. For the CPB:

   - Solve a linear system of simultaneous equations to calculate the prices of the different products;
   - Find the global consumptions so as to maximize the utility function subject to linear constraints;
   - Calculate the quantities to be produced in order to satisfy the global consumptions, given the technical coefficients.

2. For the firms:

   - Determine the technical coefficients so as to minimize their production costs under the given prices of their inputs.

Finally, in the Heald procedure, we have:

1. For the CPB:

   - Calculate the marginal social values of all goods;
   - Solve a set of simultaneous linear equations to determine the new allocations.

2. For the firms:

   - Calculate outputs and marginal productivities implied by their production functions and resource allocations.

It seems difficult to assess realistically the difficultues involved in each of the above computation tasks. The reason for this is that, contrary to what is assumed in the development of the procedures, in reality, utility functions, production functions and most of the other economic concepts involved are now known in an explicit form. In practice the best we can hope for is a rough approximation of these economic abstractions. Consequently, it is difficult to imagine how these tasks would be implemented the practice.

Therefore, it does not seem very fruitful to look at these computational tasks as conventional mathematical programming problems. However, due to the linearity assumptions involved in the L.S.M. procedure it seems to be the most suitable for practical application in what concerns computational difficulties. However while this computational advantage is, to a large extent, due to the assumption of constant returns to scale, this very assumption imposes a strong restriction on the nature of the economy.

The third aspect that we are considering are the assumptions about the nature of the economy. In this regard, as we have already observed during the presentation of the procedures, the Heal procedure seems to be closer to reality. While the other two dependend on the assumption of convex production possibility sets, the Heal procedure allows for the existence of non-convexities.

With respect to be convergence properties, we have already seen (subsection 5.1.3) that the L.S.M. procedure is in a general advantage over the Arrow-Hurwics procedure. The comparison between the L.S.M. and the Heal procedure does not yield a definite conclusion, since both satisfy the feasibility, monotonicity and assymptotic convergence properties. In practice the more meaningful convergence characteristic is the initial speed of convergence. Unfortunately, almost nothing is known of how the three procedures compare in this respect, and we should expect this result to depend on the specific problem at hand.



Finally, we could not avoid drawing some more general conclusions from this study.

First, we notice that the theory and the practice of decentralized planning are still very far from each other. By no means, this implies that the theoretical efforts are useless, since they provide a sound framework for analysing some important ideas of decentralization.

On the other hand, if application of the decentralized planning procedures as the only guide to short run resource allocation for the entire economy seems to be impractical, it does not follow that application to control of certain sectors of the economy is not possible and advantageous.

Three critical points for the successful narrowing of the gap between theory and practice seen to be:

a) Development of procedures requiring only readily obtainable information about consumer preferences and production parameters.

b) Fast convergence in the first few iterations of the procedure.

c) Reasonable informational and computational requirements.

Even though the present achievements of decentralized planning procedures are still far from the ideal, this should not constitute a reason for rejecting the idea of a socialist economy, since the mechanisms prevailing in the market economy are also very far from theoretical perfection.



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