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SOCIAL OBJECTIVE FUNCTIONS IN AGRICULTURAL RESEARCH

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Between 1930 and 1976, the number of farms in the United States declined by just over 50%.1/ Other changes accompanying this decline were, for example, changes in the location of production, composition of output, the size of the farm and the number of farmworkers. Between 1960-1975, U.S. farm employment fell from around 7 million to 4.4 million. During that same period, the asset-per-farmworker ratio rose to over $100,000, a rise of over 500%.

During the 1965-1976 period, real U.S. GDP rose 38%.2/ Output of the agricultural sector rose by 9% in real terms, 216% in current prices. The share of GDP originating in the agricultural sector fell from 3% to 2%. Such changes in the structure and composition of U.S. farming are both a determinant of and a result of the changes in U.S. GDP. As one of its components it contributes a portion of that output. Prosperity in the agricultural sector, therefore, contributes to overall prosperity. As a user of inputs produced in the nonfarm sector, farming productivity is affected as much by the availability of such inputs as well as by the managerial skills of the farmer.

The preceding is purely descriptive; the concern of this paper is with the normative. A further concern of this paper is the attempt to develop a means, ex ante, to judge the desirability of such changes in the future, and of the policies which give rise to them, rather than with making ex post judgments on the past. Just as the building of the pyramids did little to raise the wellbeing of their builders, so there is a danger that research designed to further increase agricultural output and productivity may be equally guilty of neglect of human values.

An appropriate starting point in the examination of values in economics is with prices. To certain economists, such prices appear to perform the role of incorporating all necessary value judgments into the domain of economics. The simplest expression of such a belief is in the price = marginal cost = marginal utility rule, P = MC = MU. From this, we see that a price is merely a counting device, or point on a scale called money, whose basic unit, at least in the United States is $1. As such, it is free of all but the purest of intentions, namely an accounting device. Only when it appears in conjunction with the above equilibrium conditions can more be said.

In a general equilibrium framework the above conditions may be restated as a Pareto Optimal state. However, although the achievement of such a state may be unimpeachable on technical grounds, it is but one of numerous Pareto Optimal points, each one a function of a certain initial income and asset distribution:

> A competitive equilibrium, even if it is also a Pareto Optimum, may involve a more unequal distribution of income than is regarded as desirable from a social point of view. The concept of a Pareto Optimum is insensitive to this consideration, and in that respect the term 'optimum' is a misnomer (Koopmans, 1957).

Consequently, the selection of any one such state as being preferable over others requires the existence of some form of preference or welfare function. As this paper is dealing with the United States and not just, for example, the wellbeing of the participants in this conference, I shall refer to this as a social welfare function.

I have referred to these basic economic concepts almost as a parable, for when we make the leap from pure theory to agricultural policy, it is well to have this parable retold. For example, I have the impression that in some eyes research is neutral as to its impacts on such states or not responsible for determining such social outcomes. Either they are the product of a Panglossian world which assures us that what is, is for the best, or they are outcomes of a benign, or perhaps neutral lottery. Yet, land is retired, crop prices guaranteed, export markets subsidized, and research channeled into some areas, not others, all of which are conscious human actions and all of which are determinants of the level and distribution of economic wellbeing.

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The National Academy of Sciences 1975 Study, Agricultural Production Efficiency, shows an 18% decline in SMYs devoted to agricultural research between 1966-1971. In some areas the numbers increased, in others they declined. In weed, insect, and disease control, they fell. In fruit and vegetable mechanization, they rose, as well as in fruit and crop production, In what sense can it be said that the results of these changes were either neutral or socially optimal? What form of social welfare function, either implicit or explicit, gave rise to these changes? Was there a split between the implicit and the explicit or between the assumed and the extant? It is my contention that only by answering such questions can we begin to judge the benefits to agricultural research.

Although I use the word "function", I am not proposing its use in the strict mathematical sense, which gives a unique ordering of states of wellbeing for all possible values of its arguments. Perhaps Sen's Social Decision Rule may be more appropriate, but here I avoid such taxonomic questions (Sen, 1970). Thus, for example, if we use the compensation principle whereby we judge a change as acceptable if the gains to the winner could potentially compensate the losses to the loser, this would be one form of such a rule or function.

In numerous economic changes, which certainly include those brought about by much agricultural research, we find that prices do not adequately measure costs and benefits due to the nonmarginal character of those changes. Here we have the familiar problem of index numbers, the problem of changing the weights, namely prices, by which we add the physical inputs and outputs. We would also consider the amount of consumer and producer surplus generated, in order to determine the total costs and benefits of policy induced changes.

To recapitulate, we would need to modify our reliance on GNP data which makes no value judgments on distributional matters: $1 = $1 = $1, irrespective of who receives it. We would, therefore, need to make explicit judgments on income distribution, as well as make corrections for nonmarginal economic changes, as well as for cases where $P \neq MC$ for other reasons, such as market imperfections.

If we achieved this economic purity, would we have achieved the challenge I am making to the participants? Unfortunately not, for many outputs of an economic system are not priced, and therefore will not be captured by our improved cost/benefit calculus unless we also include them. I shall refer to these outputs as externalities, to include public goods as a special case.

I would argue that externalities are just as pervasive in agriculture as they are in other economic sectors, and that such externalities affect both the agricultural and nonagricultural sectors. It is not my intention to be encyclopedic, but merely to suggest a few examples to illustrate the problem.

Most textbook examples deal with the spillover type of externality; the acid rain effect of a smokestack on neighborhood structures; the effect of a dam on the value of land downstream; the provision of fruit trees benefiting the beekeeper. These examples combine both pecuniary and technological externalities which I shall not distinguish in this paper.

Let me begin with the bête noir agricultural research, the use of DES in cattle fattening, and combine this with another 'D', the use of DDT in crop production. Both are recognized to have severe external effects. From a social point of view, the costs and benefits of their use may diverge from the private evaluation.

For my second group, let me again take two examples, the production of gasohol and the mechanization of crop production and harvesting. Current gasohol production research proposals seem to point to two alternative systems. One, operating on a small scale, would enable farmers to convert grain to alcohol in stills sited on the farm. The other envisages one commercial still producing at a level which would probably produce the entire U.S. output. There appears to be a considerable difference in the efficiency of the two systems. On the other hand, there may also be considerable equity implications of the final choice, and therefore a need to consider the equity/efficiency trade-off. In this example, there is an awareness of the problem and of the possible social costs, but in the mechanization problem we typically examine the costs ex post. The social costs of mechanization in cotton and tomato picking were probably not considered at the time such developments were introduced. But the farmers in California who are threatening legal action against their university for financing the research which gave rise to these changes are essentially asking this question: "What type of social welfare function was used which judged that the public funds used to finance this research had a greater social rate of return in this use than in, for example, insect control?" Or to state the problem on an even more basic level: "Which social welfare function was used which judged the gains to the large commercial grower to outweigh the costs incurred by the small producer?"

I am not, for one moment, arguing that the entire process of economic development has had a net social cost. But I am arguing that, just as in the first set of problems, such distributional problems cannot be assumed away. In my third example they become even more critical, for in looking at the impact of agricultural development on the rural economy we can often see the externalities in the abandoned small towns and lost jobs. The problems which arise in this context have been well discussed in Benefits and Burdens of Rural Development (C.A.R.D., 1970) and in Focus on Iowa (C.A.R.D., 1972), but I raise the issue here as an example of some of the externalities associated with the changes in scale and input mix described in the introduction to this paper.

I now turn to consider the consequences of neglecting the importance of such externalities. The first one, although merely a definitional consequence, is that market prices cannot be used as socially optimal indicators of costs and benefits. The second consequence is a tendency to generate hostility to the cause of the externality on the part of those bearing the external cost. I would be hesitant to draw a causal connection between such hostility and the decline in SMYs referred to above, but at the least such objections do not support an expanded research program.

The third consequence is frequently encountered, that of reaction rather than action. Environmental impact statements and lengthy legal proceedings would not disappear if the concerns of this paper were adequately recognized, but I have a strong feeling that an anticipation of such issues, an attempt to incorporate them into the early decisionmaking or the involvement of various parties affected by such decisions, these would be steps to reduce the costs of reaction. Moreover, I am also suggesting that such considerations also be incorporated into the research design and development phase.

My concerns so far have been with what should be done, but not how. I am unaware of any social objective function lying on the shelf ready to be used, but at the same time I am not daunted by the impossibility theorem that no such function can exist. The proposal which follows is therefore not to be seen as an attempt to provide the social welfare function, but a less ambitious attempt to incorporate the above social concerns into agricultural planning.

Planning Proposal

The proposal considers the experiment station director as responsible for maximizing some objective function by allocating a given budget, subject to various additional constraints as yet undetermined. Given the transformation from budget to SMYs, the latter takes on the role of the main constraint. The maximand consists of outputs which are changes in knowledge, both embodied and disembodied.

The problems to consider in such a model are: (1) measures of inputs and outputs; (2) the level of specification of outputs on a means-ends continuum in order to determine the arguments in the function; (3) the structure of the matrix of research activities; (4) the number of arguments in the objective function; and (5) the form of the function, and therefore, the form of aggregation over individuals and over inputs.

I consider the proposal as a guide for those involved in the decisionmaking process, the exact specification to be determined in the context of the specific circumstances. It is based on the work of Dalkey (1972) and Van Gigch (1974). Dalkey's work, at UCLA and the Rand Corporation, has become known as the Delphi--"Know Thyself"--experiments. These were undertaken by Dalkey and others to test whether or not groups were capable of making group judgments, on both factual matters and on value judgments. Says Dalkey: "...as the studies in the following chapters show, individuals can make numerical judgments concerning the relative importance of basic life values, and these numbers are not capricious" (1972, p. 7).

The Delphi technique, as originally devised, was concerned with small group decisionmaking. This has been used both to obtain group expert opinion as well as to obtain a list of variables with their respective values which are considered the most important quality-of-life variables (Dalkey, 1972). Underlying this approach are three conditions: (1) reasonable distributions, (2) group reliability, (3) change, and convergence on iteration with feedback.

Work on the Delphi method has been further developed by Turoff who, by examining the different uses of the Delphi approach, has pointed out its appropriateness in different circumstances and the modifications these require to the general procedural principles (Turoff, 1975). Thus, in this respect, it is essential to distinguish between two aspects of a Delphi analysis.

(a) Defining the structure of the problem, the impacts and consequences of various outcomes and activities. As examples of this type of work, Turoff refers to Longhurst's work in analyzing the effects of pre/post natal care on I.Q. Given the lack of a suitable model, two Delphi groups were established to determine the relevant components to include in the study, and to assess the results of various programs. Jilson (1975) refers to this aspect of the work as the development of a transition matrix. Economists refer to this as a structural model.

(b) The second aspect is the evaluation of various programs in terms of objectives or goals, these, in turn, being either the product of a

Delphi experiment or provided by another source.

It is essential in any Delphi procedure that these two aspects be clearly distinguished. Failure to do so will result in a confusion between what is feasible and what is desirable, or, in Turoff's words, in disagreements which may arise out of differences in uncertainty or information and differences in self-interest.

Although the purpose of this study is to determine the set of weights to be used in policy evaluation, it will be argued that in all but a purely formal sense such an exercise also requires a knowledge of the structural model. Two reasons may be given in defense of this argument. The first, as just mentioned, rests on the need to be able to distinguish between the goals and constraints of a problem. The second arises from the need to determine what the outputs of such a system are together with the need to specify goals at a common level on a means-ends continuum.

For these reasons, this proposal considers establishing two Delphi groups. The first is known as a Policy Delphi (PD), which describes the structure of the matrix of research inputs and outputs. The second, the Goals Delphi (GD), is designed to evaluate the desirability of various research outcomes, or alternative budget allocations.

Goals Delphi Alternatives

The objective of this section will be to review alternative procedures the goals Delphi might adopt to assist in improving station budget decisions. Some attempt will be made to examine various approaches found in a rather diverse body of literature, in order to understand the differences in design and circumstances of these approaches.

The first distinction to be drawn is between formal or normative and descriptive or institutional procedures. The latter are illustrated by Simon's "Carnegie" method in which the decisionmaking process itself is an essential ingredient for interpreting the consequences or outcomes of organizational decisions (McFadden, 1975). The former, which account for the bulk of such models in economics and management science, can be described as attempts to adapt the utility maximization concepts of individual choice theory to an organization, group, or bureaucracy.

Within this second group are to be found a variety of techniques for both understanding organizational behavior and providing optimal decision rules and guidelines. The first type will be referred to as an optimum budget allocation procedure. This is illustrated by the work of Strauss (1975) and also appears to be the direction in which Kaldor was heading in his use of the priority approach (1975). Kaldor's procedure was based on the principle of an optimal allocation of a given budget being reached where the marginal return to a dollar was equal from all possible activities. In Kaldor's development of this principle, a panel was to be given the opportunity to transfer funding in such a way that when no further reallocation was deemed desirable, such an optimum was reached.

Where market prices exist, net-present-value and rate-of-return techniques are an approximation to this approach, allowing for the fact that the size of certain projects may not be sufficiently flexible to permit a common return or benefit at the margin. Instead, projects may be ranked, with the marginal project being defined as the one which just exhausts the budget as one moves down the list of projects in decreasing order of benefit.

A second class of techniques requires estimates of demand functions, parameters being specified either as unit-dependent or as elasticities. As an example of the former, Deacon and Shapiro (1975) estimate a demand function for both environmental quality and rapid transit by means of a logit analysis of voting patterns in California. Using more familiar regression analysis, Bergstrom and Goodman (1973) estimate, among others, income and tax share (price) elasticities for police, parks, and general municipal activities.

Given that a demand function is based on the principle of utility maximization, any point on that function is regarded as an optimum. However, where prices are not known even the existence of such a function will not be of any assistance in budget allocation.

The third approach, one which appears to have dominated studies of organizational behavior, attempts to obtain either the weights or a complete specification of a preference function itself.

A representative selection of the revealed preference approach to developing such knowledge can be found in the work of McFadden (1975), Friedlaender (1973), Hori (1975), and Rausser and Freebairn (1974). The basic citicism of such work, in addition to that of Makin (1976) concerning identification problems, is to be found in Johansen's outstanding survey (1974). Where a demand function cannot be estimated due to inadequate data or lack of time to test consumer behavior, it is necessary to attempt to measure the utility function directly. However, this is precisely the situation in which it is most difficult to obtain such a function.

In addition to imaginary interviews (Eijk and Sandee, 1959) and variations on this approach, we are left with attempts to obtain preferences in two further ways. One, followed by Frisch (1976) uses a direct interview technique to build up the shape of a preference function. The other, closely related to it, consists of more experimental attempts to obtain such preferences by offering varying commodity bundles and recording choices made (MacCrimmon and Toda, 1969; Rousseas and Hart, 1951).

Despite these differences, these last two methods exhibit sufficient similarities to be subject to several of the criticisms raised by Wallis and Friedman (1942) against such methods, these being based on the artificiality or experimental nature of such attempts. However, it would appear that these criticisms are themselves more appropriately concerned not with the attempt to study choices and preferences, but with the attempt to completely specify the range and shape of the preference function. If this degree of exactness is not required then the criticisms themselves are weakened.

The work of Geoffrion, Dyer and Feinberg (1972) is proposed here as the basis for the policy Delphi for this reason. This method combines both the normative and descriptive branches described above, enhancing the applicability of the proposal. For, as noted by Zimmerman (1977): "Without any understanding of the environment, including the institutional framework, normative models are likely to be exercises in applied mathematics." Decision information systems, on the other hand, by allowing for feedback and sensitivity testing permit solutions to be obtained in situations in which the direct quantification of multiple criteria leaves much to be desired (Baker and Freeland, 1975).

We may also note the comments of Fox (1972) in the context of a similar problem, that of resource allocation in a university department, in which "The idea of an objective function to be optimized would probably improve the decisions of the Chairman and Dean, whether or not formal computations were used."

An Interactive Approach to Multi-Criterion Optimization

Following the work of Geoffrion et al (1972), we review a procedure for the Goals Delphi to follow, as described in the following steps:

(a) An initial point is defined which measures the level or rate of activity in either dollar terms or in SMYs. Note that these measures are the sum of inputs in the means-ends hierarchy up to that point. Where, as is most likely, the activity at one level jointly contributes to that of several others above it, some rule to apportion these inputs will be necessary, to be determined by the Policy Delphi.

(b) A set of weights, expressing the trade-off between all pairs of activities, to be determined by the Goals Delphi. In an ordinal specification these weights may be specified as relative to some arbitrarily chosen reference criterion, or numeraire, say activity 1. At this stage, it is not necessary to constrain the range within which these weights are valid. We also note that if, for example, w_2/w_1 and w_2/w_3 are known, yet difficulty exists in determining w_3/w_1 directly, we can obtain this from $\frac{w_2}{w_1} \cdot \frac{w_3}{w_2}$.

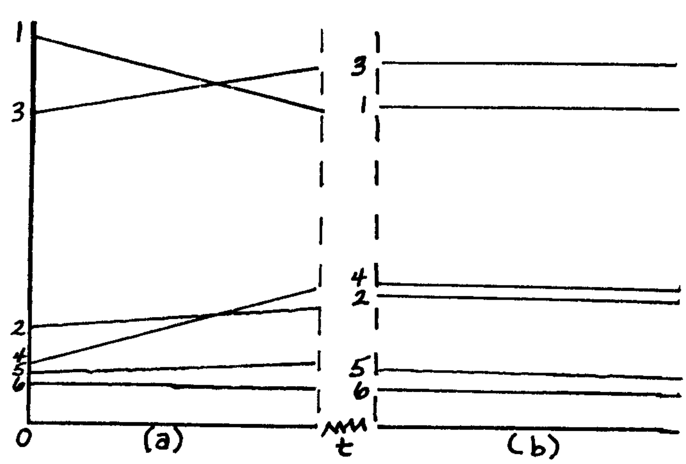
The technical basis for this approach is contained in Appendix 1.

(c) Given the weights above, the procedure requires a solution to the direction-finding problem which maximizes the preference function given those weights (see Appendix, equation 2'). The levels of each activity, some rising, some falling, will vary with the size of the step or range over which the relative weights are allowed to hold. Thus, for example:

Figure 1

Activity/Title	S.M.Y.s	A	B
1. Crops	300	1	1
2. Extension	30	4/15	5/15
3. Livestock	200	2/3	5/6
4. Soils	60	1/5	4/15
5. Nutrition	50	1/6	1/4
6. Forestry	40	2/15	2/15

A = existing trade-off.
B = revised references.
(a) = solution using B.
(b) = optimal solution after k^{th} revision.



(d) In Figure 1 the solution to the output or activity levels is determined without an optimal point being selected. This is done by determining t, the size of the step, which is here given as .75. In selecting t the Goals Delphi is selecting a most preferred point at that level of activities.

(e) The procedure is then run through a second iteration. The Goals Delphi selects a new set of relative weights with the solution at (d) as the new reference point. Given that the procedure is searching out an optimum we would expect less changes in relative weights at each round of the iterative procedure until an optimum is reached. At such a stage, if we were to repeat Figure 1 we would find the lines drawn to be virtually horizontal.

Several comments may be made to conclude this section. As will be evident from the above description, the success of the procedure requires a monitor who is fully conversant with the procedure. Secondly, the interaction between goals and results is an essential part of the procedure providing interaction and feedback to the participants. In this lies its advantage over more abstract attempts to formulate goals. While the latter may be desirable, as normative guides they are less useful as descriptive aids to solving problems of resource allocation.

Thirdly, by not requiring a complete specification of an entire preference function, the question of the validity of the range over which the weights hold does not arise.

Finally, it should be noted that no a priori restrictions are placed on the aggregation of individual preferences within the Goals Delphi. This applies to both the individual weights and the method by which these are summed to provide group preferences. A number of decision models (Bacharach, 1975; Keeney and Kirkwood, 1975; Freimer and Yu, 1976) tend to be guilty of what Van den Bogaard and Versluis (1960) describe as the assumed Law of the Medes and Persians that the scaling constant, λ, to aggregate individual preferences, must be linear. Nor does such an approach rely on minimizing sums of squares or R^2 coefficients to determine consensus or agreement (Ford et al, 1978). Nor does it make the mistake, as shown by Haefele (1973), of assuming the arithmetic mean of the individual optimal decisions is the socially optimal one (Bogaard and Versluis, 1960).

Composition of the Delphi Groups

(1) Policy Delphi. The two alternatives one may consider are:
(a) one representative from each scientific discipline involved in station research, and (b) the basis for representation to be weighted by the number of SMYs in each discipline.
Using (b) as a basis would be treating each discipline as a constituency, with the initial distribution of power weighted by relative SMYs. However, the purpose of the Policy Delphi is to be analytical, providing input and advice, not to be representative. Accordingly, (a) is suggested.

(2) Goals Delphi. Here we may consider three bases for selection: (a) the station director selects to maximize the long-run funding of the station, (b) one representative from each interest group affected by station research, as discussed in section IV 3. (c) territorial-based representation, for example, one representative per state legislative district.
Proposals (a) and (b) are obviously closely related, in that one way of maximizing long-run station funding is to select representatives from economic groups receiving the greatest economic benefit and overlooking those whose economic standing may be harmed. As such both are examples of dollar representation referred to above. However, insofar as this proposal is an attempt to break away from the inherent conservatism of such a structure, this would be an unacceptable basis for representation. It would, for example, violate Tinbergen's "principle of the fundamental equality of man" (1972). As Haefele (1973) has written:

> "The dollar vote is of obvious usefulness in corporate management and similar concerns where dollars are at risk. When lives, tastes and wills are at issue, the dollar vote has little to recommend it."

While the principle of territorial representation has much to commend it, the practice of establishing such a group may pose certain difficulties. Not the least of these is that establishing a Delphi group in this situation is not an attempt to duplicate a legislature but to establish a smaller group following legislative principles in reaching decisions.

To select such a small group, we may consider using some random sampling procedure such that the composition of the sample is designed to reflect the underlying population. For example, the state of Iowa could be split into n-regions, with each region having an equal likelihood of being selected. By random selection, a sample of representatives could be drawn whose decisions would be taken as representative of the larger constituency. No simple procedural rule lies on a shelf waiting to be used in circumstances such as these, but the problem is not insoluble.

Concluding Remarks

My hope is that I have indicated the possibilities for incorporating social concerns into experiment station budgeting. Of course, I hope to see this challenge picked up, that the outlines can be filled in with the experience of experimenting with the proposal. I also hope that the word "challenge" not be misconstrued as a threat to any particular discipline. The benefits of possibly larger research finding, contingent on the improvements this proposal makes over current practices, could well accrue to all parties.

Footnotes

1/Data from Sundquist, 1977.

2/Data from O.E.C.D., 1976.

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Appendix 1

Mathematical Specification of Model

Following Geoffrion, et al (1972), we have:

(1) $\text{Max } U[f_1(x), f_2(x), \ldots f_r(x)], \quad \text{s.t. } x \varepsilon X$

where: x is the vector of decision variables, f_i are the outputs associated with x, U is the decisionmaker's utility function.

To solve the above problem in an iterative interactive approach of k steps, set k=1, choose the initial level of station activities as x_1, and solve for an optimal solution to y_1, the direction in which the r functions proceed in Step 1.

(2) $\text{Max}_{y \varepsilon X} \quad \nabla_x U[f_1(x_k), \ldots, f_r(x_k)] \cdot y$

Setting $d_k = y_k - x_k$.

(3) $\text{Max}_{0 \le t \le 1} \quad U[f_1(x_k + td_k) + \ldots, f_r(x_k + td_k)]$.

(4) Setting $x_{k+1} = x_k \text{ T } t_k d_k$, $k = k+1$, the procedure is iterated back to step 1. The size of t maximizes the utility of the decisionmaker.

As an approximation to U, using the chain rule, (2) becomes

(2') $\text{Max}_{y \varepsilon X} \sum_{i=1}^{r} w_i^k \nabla_x f_i(x_k) \cdot y$

where w_i^k gives the (ordinal) trade-off between

$$(\partial U/\partial f_i)^k / (\partial U/\partial f_1)^k \qquad i = 1 \ldots, r,$$

with x_1 being chosen, arbitrarily, as the reference, or numeraire.

The iteractive nature of the approach is demonstrated in step (3), where the solution to (2) given the w_i^k is generated for the unit range $0 \le t \le 1$. The decision maker then selects a value for t which in turn determines x_k, permitting x_{k+1} to be determined and so on.

Using the procedures discussed in the text, we see that the Goals Delphi is responsible for the determination of w_i^k. The Policy Delphi is responsible for the specification of f(x), and the monitor is responsible for solving for the solution to (1) at each step.