ON OPTIMAL ECONOMIC POLICY MAKING USING STOCHASTIC METHODS [1]

Nazrul Islam, Salilesh Mukhopadhyay and Jadunath Pradhan [2]

ABSTRACT

In agrarian economies the success of new agricultural technologies depends on the appropriateness of policy combinations implemented by these governments In this paper different methods to optimise the related policy-mix are outlined in brief Using the results of an econometric model the goal-seeking method of the SAS package has been applied to deterministically obtain optimal policy

Lastly the techniques of equilibrium programming are used to derive an equilibrium (optimal) strategy for the associated non-zero sum stochastic game between two players

Key Words: Optimal policy, Equilibrium programming

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[2] Respectively, Program Evaluation Unit, Department of Agriculture, Western Australia, Department of Statistics and Operations Research, RMIT University, Melbourne, and Department of Applied Economics, Victoria University of Technology, St Albans, Melbourne The authors wish to express their sincere gratitude to John Quilkey for his encouragement to model policy optimisation. The authors also acknowledge the support of Ali Khan for providing access to his field data

1 Introduction

Policy makers and governments in most developing countries have relied, and may continue to rely, on adoption of the new agricultural technology as crucially important to their development strategies notwithstanding the gap in knowledge about the adoption behaviour of farmers In developing countries there were high hopes that the new technology would set the preconditions for a Rostovian 'take-off' and sustained growth in these relatively poor economies It was hoped that the new technology would not only stave off hunger and malnutrition by raising incomes, output and consumption of farm household but would also generate marketable surpluses of food for the urban-industrial sector and create employment opportunities for rural agricultural labours (Mellor 1969a; 1969b and Schultz, 1964) To achieve these objectives, governments of agrarian economies followed an array of price-income and structural and institutional policies for the promotion of dissemination of this technology among farmers In terms of some of the major macroeconomic indicators, a degree of success has been achieved in the adoption of new technology and the growth of agricultural output Substantial research has also been carried out to assess the relative importance of different agricultural policies and their implications for the welfare of farm households and other developmental goals of generating marketable surpluses and creating employment opportunities (Pradhan, 1991) However inadequate attention has been accorded to the determination of an optimal policy-mix based on the economic environment within which farm decisions are made

In the economic modelling of development issues the conventional practice has been to develop the theory to explain decision making behaviour of economic agents with respect to the introduction of 'new technology', to evaluate the effectiveness of commonly pursued policies and to assess their implications for welfare and other development goals. Arbitrary policy shocks are, under this methodology, introduced into the model and an assessment is made of their impact and distributional incidence In addition researchers have been concerned to find out which policy shock positively changes the decision making behaviour of the economic agents towards the fulfilment of welfare and development goals A problem inherent in this approach is that unless policy variables are considered predetermined the model cannot be closed Therefore the determination of an appropriate policy-mix which can influence changes in the decision making behaviour of economic agents at the level desired by planners and policy makers has not been practical (Islam, 1991) In addition, no substantive attempt has been made to determine optimal policy-mixes which account for the decision making behaviour of farmers with respect to the adoption of new technology Improved understanding of how an optimum policy-mix may be determined taking economic agents' decision making behaviour into account, may help bridge the gap between targets and achievements of policy decisions

In this paper different methods to optimise the related policy-mix are outlined in brief. Using the results of an econometric model the goal-seeking method of the Statistical Analysis Systems (SAS) a software package has been applied to deterministically obtain optimal policy.

The last section presents an alternative approach to optimal economic policy making. The usual trend in optimising economic policies is by dynamic programming. Recently Iwamoto (1994) has developed an algorithm for bipolicy interaction for the general bidecision process. In this paper the techniques of equilibrium programming (EP) is applied in game theory It is evident that by varying the payoff matrix different equilibrium solutions result and in several such cases the solutions would be mixed policies, ie. a 'policy-mix' situation arises

2 Methods of Policy Optimisation

Optimum policy may be defined as a set of policies which a decision maker must choose from a given set of alternative policies to achieve a set of policy targets In national macroeconomic planning decision makers choose among alternative fiscal, monetary and other policies to achieve national economic goals In corporate capital planning decision makers choose among alternative investment projects and at the international level the decision makers of an international development agency choose among alternative development projects to achieve their development objectives

In econometric modeling several approaches are used for policy evaluation Depending on the problem and on the formulation of the econometric model mainly three alternative approaches, such as the *instrument- target approach*, the *social-welfare-function approach*, and the *simulation approach*, are used[3] As there are some difficulties with the first two approaches the simulation approach is more widely used for policy evaluation using an estimated econometric model This approach avoids the necessity of assuming either the existence of desired levels of endogenous variables, as in the instrument-targets approach, or the existence of a well-defined objective function to be maximised, as in the social-welfare-function approach

In general, *Simulation* refers to the determination of the behaviour of a system via the calculation of values from an estimated model of the system The model is sufficiently explicit so that it can be programmed for numerical study The system's numerical behaviour is then determined (simulated) under different assumptions in order to analyse its response to a variety of alternative inputs Each simulation run is an experiment performed on the model, determining values of endogenous variables for alternative assumptions regarding the policy variables, other exogenous variables, stochastic disturbance terms, and values of parameters

The problems in all these approaches, as mentioned by Intriligator (1978), are reiterated below In instrument-target approach there are three problems in policy optimisation One is that it assumes no tradeoffs among the targets, but rather specifies fixed values for each The second is that it is doubtful that policy makers would or perhaps even could reveal specific target choices The third is that of a shortage of independent instruments

The problem with the social-welfare function approach, whether of short-run or of the long-run optimal control form, is that the parameters and even the specific form of the objective function are not known and cannot be elicited from policy makers in any practical way

However, in simulation approach, each simulation run is an experiment performed on the model, determining values of endogenous variables for alternative assumptions regarding

[3] For the detail of these approaches see Intriligator (1978).

policy variables, other exogenous variables, stochastic disturbance terms, and values of parameters If the policy makers were able to formulate objectives in the form either of targets or of a social welfare function, the econometric model could be used to determine optimal policy for these objectives Here the process of simulation could be reiterated, with the policy maker eventually choosing a specific policy, guided by the optimal policy implied by the objectives and model

The goal-seeking approach is in fact one form of simulation approach which allows to solve the model backwards to compute predicted values for the exogenous (policy) variables consistent with given values of the endogenous (dependent) and target/goal variables

If a model equations defined in a system of normalised-form equations as

$$Y = F(Y,X,\theta) + \varepsilon$$

where Y is a vector composed of the endogenous variables, X is a vector composed of the independent (exogenous) variables, θ is a vector of parameters of the model, **F** is a vector-valued functions computing the predicted values of the endogenous variables, and ε is a vector of random errors

The model equations could also be defined in a general-form system of equations as

$$\varepsilon = \Theta(Z,\theta)$$

where Z is a vector composed of all model variables (the combination of X and Y). The advantage of the general-form equations approach is that the decision about which model variables are to be regarded as dependent (endogenous) and which as independent (exogenous) is not part of the model structure This allows to decide which variables to solve the model for in terms of given values of the other variables[4]

In this paper, firstly, by using the 3SLS method the numerical behaviour of an agricultural household system, developed by Khan, Islam and Quilkey (1993) is determined, ie the parameters are estimated Secondly, these parameters are used to determine the values of a subset of exogenous (policy) variables by setting the values of other variables at their mean level

The basic model used in this paper is the farm household model developed by Pradhan and Quilkey (1991) Khan, Islam and Quilkey (1993) applied the PQ model using data from Pakistan agriculture The foundation of the KIQ model based on the PQ model is presented below This theoretical foundation has been used as a background for the empirical specification and estimation of the KIQ model.

[4] For the detail of the estimation procedures see the SAS/ETS User's Guide, Version 6, First Edition, Chapter 13, Page 315-397.

3 The Foundation Model

The theoretical foundation of the agricultural household model which is based on the integration of production and consumption choices, has its origins with Chayanov (1925) and in the subsequent works of Tanaka (1962), Nakajima (1957), Mellor (1963, 1969), Millar (1970), and Pradhan and Quilhey (1993) In subjective utility theory household behaviour is considered to be an outcome of the interaction between a production function and a utility function

The theoretical model presented in this section is based on the PQ model The foundation of the PQ model is based on three functional relationships One is the 'output function', second is the 'consumption function' and the third is the 'real balance constraints' These three functional relationships which characterises farm-household decision making process in peasant economies are implicitly specified below Based on these three functions the structural relations of the farm-household model in the form of an systems of equations are developed in this section[5]

The output function

$$Q_T = Q_c + Q_m = F(L_{fs}, \pi, X_i) \tag{1}$$

where,

Q_T = the total production,
Q_c = the level of consumption,
Q_m = the market surplus,
L_{fs} = the labour supply,
π = the rate of technology adoption, ie the proportion of land allocation to new technology
X_i = the i^{th} exogenous variables

The utility function

$$U = U[Q_c, M, L_{fs}(S_i), L_{ms}(S_j)] \tag{2}$$

where,

U = the level of household utility,
M = the other all consumption goods besides the subsistence good,
S_i = the i^{th} specification of variables associated with on-farm labour supply,
S_j = the j^{th} specification of variables associated with off-farm labour supply.

[5] For theoretical arguments behind these structural relationships see Pradhan and Quilkey (1993). In KIQ model, as compared to PQ model, the hired labour and the cash input variables were not included because in practice farmers in the study area in Pakistan commonly do not use these two inputs.

Real Balance Constraints (ie. Cash-flow identity)

$$P_sQ_m + Y_n + W_mL_{ms} - M - S = 0 \tag{3}$$

where,

P_s = the price of marketed surplus,
Y_n = the nominal unearned income,
W_m = the off-farm wage rates,
S = the savings that may be carried over from year to year

The empirical optimisation problem of semi-subsistence agricultural household implies maximising the utility function (2) subject to production function (1) and real balance identity constraints (3) Applying the general methodology of Lagrangian multipliers we get

$$\begin{aligned} L &= U[Q_c\,, M\,, L_{fs}(S_i)\,, L_{ms}(S_i)] - \lambda_1[Q_c + Q_m - F(L_{fs}\,, \pi\,, X_i)] \\ &\quad - \lambda_2(P_sQ_m + Y_n + W_mL_{ms} - M - S) \end{aligned} \tag{4}$$

Where, λ_1 and λ_2 are Lagrangian unknowns

By multiplying (4) partially with respect to the unknown variables Q_c, M, L_{fs}, Q_m, π, λ_1 and λ_2 the following first order conditions can be obtained

$$L_{Qc} = U_{Qc} - \lambda_1 = 0 \tag{5}$$

$$L_M = U_M + \lambda_2 = 0 \tag{6}$$

$$L_{Lfs} = U_{Lfs} - \lambda_1 F_{Lfs} = 0 \tag{7}$$

$$L_{Lms} = U_{Lms} - \lambda_2 W_m = 0 \tag{8}$$

$$L_{Qm} = -\ \lambda_1 -\ \lambda_2 P_s = 0 \tag{9}$$

$$L_\pi = \lambda_1 F_\pi = 0 \tag{10}$$

$$L_{\lambda 1} = Q_c + Q_m - F(L_{fs}\,, \pi\,, X_i) = 0 \tag{11}$$

$$L_{\lambda 2} = P_sQ_m + Y_n + W_mL_{ms} - M - S = 0 \tag{12}$$

Where the subscripted 'L's, 'U's and 'F's are partial derivatives of the relevant functions with respect to the indicated subscript variables From equation (5), which provides the linkage between the consumption and production of the farm household, we get

$$\lambda_1 = U_{Qc} \tag{13}$$

Using the value of λ_1 from (13), the relative prices of other consumption goods can be obtained from the linkage equation (9) between the real and nominal sectors as

$$\lambda_2 = -\lambda_1/P_s = -U_{qc}/P_s \tag{14}$$

The Lagrangian unknowns can be eliminated from the rest of the first order system of equations by using their values from (13) and (14) The resulting system of equations defined in implicit form may be treated as the structural relations of the farm household model

Substituting (14) into (6) we get **other consumption goods function** as

$$U_M - U_{Qc}/P_s = 0 \tag{15}$$

Similarly substituting (13) into (7) we get implicit **on-farm labour supply equations** as

$$U_{Lfs} + U_{Qc} F_{Lfs} = 0 \tag{16}$$

Off-farm labour supply equation as

$$U_{Lms} + (U_{Qc}/P_s)*W_m = 0 \tag{17}$$

Rice technology adoption equation as

$$U_{Qc}F_{\pi} = 0 \tag{18}$$

Total output equation as

$$Q_T = Q_c + Q_m = F(L_{fs}, \pi, X_i) \tag{19}$$

The output and disposal identity as

$$Q_T = Q_c + Q_m \tag{20}$$

The real balance identity as

$$P_sQ_m + Y_n + W_mL_{ms} - M - S = 0 \tag{21}$$

Equations (15) through (19) constitute farm household model consisting of a system of seven equations in seven endogenous variables

4 The Empirical Model and Policy Application

4.1 The empirical model

The theoretical and empirical apparatus of the KIQ model has the following properties:

(1) the farm household data are cross-sectional,

(2) the farm-level determinants of adoption are classified as technological and socio-economic,

(3) the farm household is viewed as a producer, consumer and resource-owner.

The KIQ model is essentially an input demand model that is constrained by exogenous (including supply) factors Both demand and supply are assumed to be observable at the village level Within a village, farmers differ from each other in their demand for an input, but face essentially a common set of supply considerations Villages differ from each other in terms of the supply curves they face, and each farmer's relationship to the supply factors is characterized by his location within a well-defined village situation.

The structural model specified in this section is a slightly modified version of the KIQ model The KIQ model is modified by adding and subtracting one explanatory variable from each of the behavioural equations without causing a major change in the behavioural relationship of the model These changes were made for better estimates of the model. Using premonition, experience, quality of data and in particular structural linkages in the model explanatory variables in each structural equations are specified. The structural specification of the model is given below.

On-farm Labour Supply Equation

$$\begin{aligned} FL &= \alpha_1 + \beta_{11}TWA + \beta_{12}VTTG + \beta_{13}TOFL + \beta_{14}RNVWA \\ &\quad + \beta_{15}TFMA + \beta_{16}TWA^2 + \beta_{17}RDM + \beta_{18}PTP + \varepsilon_1, \end{aligned}$$

Total Farm Wheat Output Equation

$$\begin{aligned} TFOW &= \alpha_2 + \beta_{21}FL + \beta_{22}\,RNVWA + \beta_{23}VTTG + \beta_{24}LITR \\ &\quad + \beta_{25}F_1 + \beta_{26}F_2 + \beta_{27}FL^2 + \beta_{28}PTP + \varepsilon_2; \end{aligned}$$

Total Off-farm Income Equation

$$\begin{aligned} TOFL &= \alpha_3 + \beta_{31}FL + \beta_{32}ICAW + \beta_{33}TFE + \beta_{34}RDM + \beta_{35}TQ \\ &\quad + \beta_{36}TFMA + \beta_{37}FWC + \beta_{38}VTTG + \varepsilon_3; \end{aligned}$$

Total Family Expenditure Equation

$$\begin{aligned} TFE &= \alpha_4 + \beta_{41}FWC + \beta_{42}ICAW + \beta_{43}TQ + \beta_{44}TFMA + \beta_{45}TOFL \\ &\quad + \beta_{46}RDM + \varepsilon_4; \end{aligned}$$

Wheat Technology Adoption Equation

$$RNVWA = \alpha_5 + \beta_{51}FL + \beta_{52}LITR + \beta_{53}ENT + \beta_{54}ENT^2 + \beta_{55}EXCT + \beta_{56}PUP + \beta_{57}PTP + \varepsilon_5;$$

Income Clearance Identity

$$(ICAW + TOFL) - (TFE + TQ) = 0,$$

Output Clearance Identity

$$FWC = TFOW - QWS;$$

Definition of variables

TFOW = the total farm wheat output measured in maunds (mds) (1md = 37.38 kg)

FL = the amount of on-farm family labour supplied to the farm firm for wheat cultivation and is measured in man-days of eight hours

RNVWA = the ratio of the area sown to high yielding varieties of wheat to total wheat area

TOFL = the total off-farm income measured in Rupees (Rs) representing income from family members engaged in seasonal or regular off-farm employment.

TFE = is the total family expenditure measured in Rupees (Rs)

FWC = is family wheat consumption measured in maunds (mds)

QWS = the amount of surplus wheat sold by the household, measured in maunds (mds). All other variables are defined earlier.

VTTG = the investment in modern technology, used in cultivation of wheat by the farmer, measured in Rupees (Rs) [1 U.S.$ = 22 Rupees (approximately) at the time of the survey].

TWA = the total wheat area measured in kanals (k) (1 hectare (ha) = 19.76 kanals).

TFMA = the total number of family members above the age of 10, measured in numerical value representing those members of the family capable of contributing to the farming activities.

TQ = the total savings of the farm family measured in Rupees (Rs) representing the financial position of the individual household.

LITR = a dummy variable representing the level of education of the farmer (0) for illiterate and (1) for literate.

PUP =	the price of chemical fertilizer (nitrogen-phosphate) (F) measured in Rupees (Rs)
F_1 =	the amount of chemical fertilizer (Nitro-phosphate), measured in kilograms (kg)
F_2 =	the amount of farm-yard manure used, measured in number of baskets (1 basket = 20 33 kg)
PTP =	the planting time, used as a dummy variable for early planting which has the value 0 from October to mid-December and 1 from mid-December to March for late planting
$ICAW$ =	the income from the three crops, wheat, maize and potatoes and additional income generated as a result of womenÕs activities such as embroidery, sewing This income is measured in Rupees (Rs)
RDM =	is the ratio of dependents (children up to 10 years of age) to the total number of family members
ENT =	the level of experience of the farmer in dealing with HYVs and measured as the number of years
$EXCT$ =	the investment of extension services measured in Rupees (Rs) and represents the amount spent by the farmer in gaining access to the service and the amount contributed by the extension office in imparting the service.
TWA^2 =	$TWA * TWA$.
FL^2 =	$FL * FL/TWA$.
ENT^2 =	$ENT * ENT$.
ε_i =	the random error terms, $i = 1, 2, \ldots, 5$

The estimated results of the 2SLS and 3SLS methods are presented in Appendix Tables A1 trough A5

4.2 Policy application

So far static stochastic models of the above type have been used for policy making by the method of simulation Typical results from the use of this method, as applied to an estimated model of this section, are shown in Table 1. The results indicate that no single policy, as is usually the case, has desirable effects on goal variables. For example, the income policy (ICAW) has an undesirable effect on market surplus (QWS) of agricultural goods for industrial growth but has the desired effect of increasing total family expenditure (TFE) which may be welfare improving Similarly, the policy of increased experience (ENT) has a positive effect on market surplus but a negative effect on total family expenditure. Yet some or all such conflicting goals may be the policy choice variables on

Table 1: Simulation results of policies on goals

Household Response (Goal) Variables	Policy Initiatives								
	20% ⇓ in Chemical Fertilizer Price (PUP) (a)	10% ⇓ in income from Crops and Womens Activities (ICAW) (b)	20% ⇑ in Farm-yard Manure (F_2) (c)	20% ⇑ in Extension Services (EXCT) (d)	2 Years ⇑ in Experience (ENT) (e)	20% ⇓ in Dependent Members (RDM) (f)	10% ⇑ in Level of Education (LITR) (g)	20% ⇑ Chemical Fertilizer (F_1) (h)	Combined Policy Effects (a + e)
On-farm family labour supply (FL)*	-0.02	-0.49	-0.04	-0.05	-5.40	0.06	-0.02	-0.08	-5.43
Total farm wheat output (TFOW)@	0.02	-0.41	1.48	0.03	-3.75	0.04	0.01	2.90	-3.78
Total off-farm income (TOFL)#	0.02	2.31	0.05	0.04	0.05	0.05	0.01	0.01	0.005
Total Family Expenditure (TFE)#	0.01	0.13	-0.01	-0.01	-0.05	-1.13	-0.03	-0.02	-0.13
Wheat technology adoption (RNVWA)	0.03	0.06	0.01	0.08	0.82	0.00	0.02	0.02	0.82
Quantity of wheat sold (QWS)@	0.02	-0.56	1.04	0.03	3.29	-0.28	0.09	2.04	3.30
Family wheat consumption (FWC)@	0.09	-0.91	0.08	0.02	2.21	-0.97	0.06	0.08	2.21

* in mandays; @ in Rupees; # in Maunds;

the part of the policy makers Simulation method does not provide much guidence as to the appropriate policy-mix or the required policy doses to achieve a set of conflicting goals It only provides the conditional policy outcomes defined in terms of target variables following a monopolicy or combined policy intervention

A second type of policy application of an econometric model, as applied to the same data and results, is illustrated by the results in Table 2 Here the role of the policy variables and goal variables are reversed Setting the goal (endogenous) variables at the target levels, numerical solutions for the policy (instrument) variables were obtained deterministically Column-3 (Table 2) results are the average values of the policy variables in the data set Column-4 values are the optimal policy outcomes when the goal variables (shown in the 'note' in Table 2) were fixed at their sample mean values Results in the last column of Table 2 show that the optimal (best) policy to increase technology adoption (RNVWA) from its current level by 10 percentage point is to reduce fertilizer prices (PUP) from 42 9 to 22 5 Rupees per bag Details about the choice of instruments, goals or targets, as well as validity of the econometric model, are beyond the scope of this paper Our main focus is on optimal policy methods It goes without saying, however, that the results are only as good as the theory or the model on the one hand and the sample data on the other

For the type of model specified in this paper no attempt has been made to implement the welfare function approach to optimal policy making The difficulty has been the faith in the ability of the researchers or policy makers to specify a reasonable criterion function However, there exists yet another stochastic quantitative method, viz., the 'Equilibrium Programming' technique which may be used more productively especially when stochasticity and an optimal policy-mix are important The methodology of this optimal policy technique is the subject of the next section of this paper

5 Stochastic Approach to an Optimal Policy

For a farming community let us consider the following five goal variables

$$(G_1, G_2, \ldots, G_5) \quad \text{and}$$

these goal variables are connected with five policy (or decision) variables

$$(P_1, P_2, \ldots, P_5)$$

with some non-linear equations

Out of these five policy variables we have three welfare improvement variables, say, E_1, E_2, and E_3 which will be called the Economic Variables and the rest two, ie T_1, T_2 are physical improvement variables, called the Technological variables.

Table 2: Optimal policy-mix for increasing technology adoption.

Policy Variables	Variable Codes	Actual	Predicted	Goal Variable RNVWA 10% ⇑
Farme spending on modern technology (Rs)	VTTG	149 285	149 298	149.298
Fertilizer price (Rs)	PUP	42 903	43 784	22.501
Total family member (age>10)	TFMA	7 127	7 128	7 128
Total wheat area in (1/19 76) ha	TWA	7 100	6.885	6 952
Total savings	TQ	430 102	430.103	430 103
Literacy level dummy	LITR	0 530	0.541	53

Note RNVWA Wheat technology adoption, ie the ratio of the area sown to HYV wheat to total wheat area
TFOW Total farm wheat output (in maunds, 1 maund = 37 38 kg.)
QWS Quantity of surplus wheat sold (in mounds)
TFE Total family expenditure (in Rupees)
FL On-farm family labour supply in man-days
TOFI Total off-farm in come in Rupees
FWC Total Family wheat Consumption

Let X_i be the probability that Player-1 plays strategy E_i for $i = 1, 2, 3$; and Y_j be the probability that Player-2 plays strategy T_j for $j = 1, 2$

such that
$$\sum_{i=1}^{3} X_i = 1,$$
$$\sum_{j=1}^{2} Y_j = 1,$$
$$X_i \geq 0$$
$$Y_j \geq 0$$
$$\forall_{i\&j}$$

The expected payoff to Player-1 is

$$f_1(X,Y) = \sum_{i=1}^{3}\sum_{j=1}^{2} X_i a_{ij} Y_j$$

and to Player-2 is

$$f_2(X,Y) = \sum_{i=1}^{3}\sum_{j=1}^{2} X_i b_{ij} Y_j$$

where, a_{ij}, and b_{ij} specify the payoffs to the two players

5.1 The Equilibrium Programming (EP) Technique:

Let us now formulate the matrix game as in EP following Zangwill (1982)

Player-1, given Y, attempts to

$$\frac{\max}{X} f_1(X,Y)$$
$$s.t. \sum_{i=1}^{3} X_i = 1 \quad \text{and}$$
$$X_i \geq 0$$
$$\forall_i$$

Player-2 given X, attempts to

$$\max_{Y} f_2(X, Y)$$

$$s.t \sum_{j=1}^{2} Y_j = 1$$

$$Y_j \geq 0$$

$$\forall_j$$

Further, we suppose that (X, Y) is an equilibrium point for the matrix game Notice that, if Player-2 uses Y, the best strategies of Player-1 is X ie, X maximises $f_1(X, Y)$ Else, there is no game situation

Similarly, suppose Player-1 selects X, then the best strategy of Player-2 is to choose Y. Once we arrive at (X, Y), neither player acting unilaterally can do better, he or she has already optimised

In the present set up, Player-1 tries to optimise the economic policy variables and Player-2 tries to optimise the technological policy variables Each Player-i, $i = 1,2$ can select from among n_i strategies The two players may have different strategic possibilities so that n_1 need not equal n_2

Also the payoff to the two players can be different If player 1 chooses strategy i and player 2 chooses strategy j, the payoff to player 1 is a_{ij} and to player 2 is b_{ij}. This concept will be more explicit from the numerical example given below

5.2 A numerical example

It is convenient to write the payoffs in a payoff table of dimension $n_1 * n_2$.

		Player - 1		
		X_1	X_2	X_3
Player - 2	Y_1	(2, -1)	(3, 2)	(-4, 0)
	Y_2	(-1, -4)	(0,3)	(-2, 1)

Let X_i be the probability that player 1 plays strategy i, i=1, , n_1 and Y_j be the probability that player 2 plays strategy j, j=1,2, , n_2

Here, $\sum_{i=1}^{n_1} X_i = 1$, $\sum_{j=1}^{n_2} Y_j = 1$ and $X_i \geq 0$, $Y_j \geq 0$, $\forall_{ij}$

Now , suppose X = (0, 1, 0), and Y = (0 5, 0.5). Because Player-1 is randomising his strategies, we must calculate the expected payoff which is

$$0.5(3) + 0.5(0) = 1.5 \qquad \text{for Player-1}$$

and

$$0.5(2) + 0.5(3) = 2.5 \qquad \text{for Player-2}$$

Again, suppose $Y = (0,1)$ and $X = (0,1,0)$ Then Player-1 plays pure strategy 2 and Player-2 plays pure strategy 2 The pay-off to Player-1 is 0 and to Player-2 is 3

For the present game the equilibrium strategy is

$$\bar{X} = (0, 1, 0)$$

and

$$\bar{Y} = (1, 0),$$

which happens to be a pure strategy The payoff to Player-1 is 3 and to Player- 2 is 2

5.3 Operational aspects

To apply the equilibrium programming technique of policy optimisation to the econometric model, it would be necessary on the part of the policy planner to identify the goal and instrument variables Just as all exogenous variables of an econometric model are not policy variables, not all endogenous variables are goal variables Only those exogenous variables which are amenable to manipulation and control are policy instruments. Similarly, only a subset of endogenous variables are of primary concern to policy makers as target variables Many endogenous variables are introduced for the purpose of closing the econometric model

In the EP method of optimal policy making each chosen goal has the same role as a player of the matrix game Therefore, subsets of mutually exclusive and completely exhaustive strategies of the selected policy variables are assigned to the goal variables based on the monopolicy simulation outcomes The magnitude of policy shocks which affect the payoffs in the game matrix are likely to have better idea about the control levels on the policy variables

Once the policy strategies and their magnitudes are determined, payoffs of the matrix game for the chosen goal combinations may be obtained from combined policy simulation results For example, if 2 years of increased experience (ENT) is chosen as a strategy for the goal variable of increasing market surplus (QWS) and a 20 per cent decrease in fertiliser price (PUP) is selected as an instrument for increase in total family expenditure (TFE), (3.30, -0.13) can be obtained from the last column of the Table 1 as a payoff in the matrix game. In this bipolicy matrix game, the market surplus (QWS) may be viewed as Player-1 and family expenditure (TFE) as Player-2. The EP technique in such matrix games will provide the optimal policy-mix and the optimal expected values for the goal variables for the chosen policies and their magnitudes.

6 Conclusions

The problems and usefulness of different policy optimisation methods on technology adoption are discussed in this paper While simulation approach is widely used for policy evaluation rather than policy optimisation, it is indicate in this paper that the 'equilibrium programming' technique could be a useful tool for policy optimisation and warrants exploring

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TABLE A1: Parameter Estimates of the 'On Farm Labour Supply' (FL) Equation (3.1)

Descriptive Names of Explanatory Variables	Variable Code Names	Expected Directional Effect	Method of Estimation			
			2SLS		3SLS	
Constant term	C	?	11.1928 **	(1.86)	10.0637 **	(1.69)
Total wheat area	TWA	+	20.4308 ***	(20.83)	20.6105 ***	(21.58)
Investment in technology	VTTG	–	–0.0553 ***	(–2.97)	–0.0502 ***	(–2.73)
Total off–farm income	TOFL	–	–0.0017 ***	(–3.25)	–0.0017 ***	(–3.38)
Ratio of HYV area to total wheat area	RNVWA	–	–16.3468 ***	(–3.69)	–14.7055 ***	(–3.37)
Total family members above 10 years of age	TFMA	+	2.3699 ***	(3.70)	2.2733 ***	(3.59)
Square term of total wheat area	TWA2	?	–0.2295 ***	(–6.08)	–0.2436 ***	(–6.68)
Ratio of dependent members	RDM	+	15.5980	(1.44)	16.7661	(1.56)
Planting time	PTP	+	14.7338 ***	(4.74)	13.7570 ***	(4.47)

<u>Equation fit measures</u>

	2SLS	3SLS
R^2 : 0.88		
$\bar{R}^2$: 0:88		
F : 8,299 df.	273.597 ***	
RMSE	22.49	22.55

Note: Figures in parentheses are calculated t–values.
*** significant at 1 per cent.
** significant at 5 per cent.
RMSE = root mean square error.

TABLE A2: Parameter Estimates of the 'Total Farm Wheat Output. (TFOW) Equation (3.2)

Descriptive Names of Explanatory Variables	Variable Code Names	Expected Directional Effect	Method of Estimation			
			2SLS		3SLS	
Constant term	C	?	-1.6619	(-0.72)	0.8499	(0.43)
On-farm family labour supply	FL	+	0.1171 ***	(4.14)	0.1741 ***	(8.38)
Ratio of HYV area to total wheat area	RNVWA	+	6.3545 ***	(2.82)	3.1452 **	(1.89)
Investment in technology	VTTG	+	0.0161	(1.80)	0.0080	(0.94)
Level of education	LITR	+	1.2260	(0.922)	-0.2223	(-0.23)
Use of chemical fertilizer	F_1	+	0.0479 ***	(4.64)	0.0179 ***	(2.57)
Use of farm yard manure	F_2	+	0.0078 ***	(1.32)	0.0031	(0.78)
Square term of on-farm family labour supply	FL^2	?	-0.0011	(-0.93)	-0.0025 **	(-3.09)
Planting time	PTP	+	-6.0171 ***	(-3.51)	-3.5883 **	(-2.56)

Equation fit measures

R^2 : 0.48
$\bar{R}^2$: 0.47

F : 8,299 df.	33.53 ***	
RMSE	11.02	11.90

Note: Figures in parentheses are calculated t-values.
*** significant at 1 per cent.
** significant at 5 per cent.
RMSE = root mean square error.

TABLE A3: Parameter Estimates of the 'Total Off-Farm Income' (TOFL) Equation (3.3)

Descriptive Names Explanatory Variables	Variable Code Names	Expected Directional Effect	Method of Estimation			
			2SLS		3SLS	
Constant term	C	?	1489.91 **	(2.14)	2045.0562 ***	(4.79)
On-farm family labour supply	FL	-	-15.8687 ***	(-6.89)	-13.6207 ***	(-8.98)
Income from crops and women's activities	ICAW	-	-0.9607 ***	(-15.23)	-1.0029 ***	(-17.64)
Total family expenditure	TFE	+	-0.9918	(-1.63)	-1.4778 ***	(-4.93)
Ratio of dependent members	RDM	+	6148.97 ***	(2.74)	7786.5008 ***	(6.24)
Total savings	TQ	+	0.7859 ***	(17.93)	0.8891 ***	(22.90)
Total family members above 10 years of age	TFMA	+	1474.6897 ***	(2.98)	1947.2759 ***	(7.98)
Family wheat consumption	FWC	+	226.6374 ***	(3.06)	178.3228 ***	(2.658)
Investment in technology	VTTG	-	4.0870	(1.78)	0.8732	(0.710)

R^2 : 0.73
$\bar{R}^2$: 0:72
F : 8,299 df. 99.039 ***

RMSE 1722.32 1975.00

Note: Figures in parentheses are calculated t-values.
*** significant at 1 per cent.
** significant at 5 per cent.
RMSE = root mean square error.

TABLE A4: Parameter Estimates of the 'Total Family Expenditure (TFE) Equation (3.4)

Descriptive Names of Explanatory Variables	Variable Code Names	Expected Directional Effect	Method of Estimation			
			2SLS		3SLS	
Constant term	C	?	867.5701 ***	(5.07)	896.0964 ***	(5.25)
Family wheat consumption	FWC	+	20.1466	(0.67)	22.1830	(0.74)
Income from crops and women's activities	ICAW	+	−0.0120	(−0.24)	−0.0729 **	(−1.98)
Total savings	TQ	+	−0.0187	(−0.509)	0.0208	(0.079)
Total family members above 10 years of age	TFMA	+	809.8285 ***	(19.01)	852.5354 ***	(24.88)
Total off−farm income	TOFL	+	0.00003	(0.001)	−0.0636 ***	(−2.74)
Ratio of dependent members	RDM	+	3239.5939 ***	(7.84)	3500.7529 ***	(8.94)

Equation fit measures

R^2 : 0.88		
$\bar{R}^2$: 0:88		
F : 6,299 df.	350.656 ***	
RMSE	797.64	809.69

Note: Figures in parentheses are calculated t−values.
*** significant at 1 per cent.
** significant at 5 per cent.
RMSE = root mean square error.

TABLE A5: Parameter Estimates of the 'Wheat Technology Adoption' (RNVWA) Equation (3.5)
(Ratio of High Yielding Varieties (HYVs) Area to total wheat area)

Descriptive Names Explanatory Variables	Variable Code Names	Expected Directional Effect	Method of Estimation			
			2SLS		3SLS	
Constant term	C	?	0.3102 ***	(4.49)	0.3143 ***	(4.58)
On-farm family labour supply	FL	–	–0.0007 **	(–2.37)	–0.0008 ***	(–2.94)
Level of education	LITR	+	0.0417	(1.17)	0.0473	(1.35)
Experience in HYVs	ENT	+	0.1633 ***	(15.08)	0.1582 ***	(14.70)
Square term of ENT	ENT^2	?	- 0.0076 ***	(–11.79)	–0.0073 ***	(–11.50)
Extension effort	EXCT	+	0.0024	(0.99)	13.7570	(4.47)
Price of chemical fertilizer	PUP	–	–0.0004	(–6.08)	–0.0004	(–1.57)
Planting time	PTP	+	0.0449	(1.11)	0.0036	(1.53)

Equation fit measures

R^2 : 0.56
$\bar{R}^2$: 055
F : 7,299 df. 53.74 ***

RMSE 0.30 0.30

Note: Figures in parentheses are calculated t–values.
*** significant at 1 per cent.
** significant at 5 per cent.
RMSE = root mean square error.