Modelling the Adoption of HYV Technology in Developing Economies: Theory and Empirics

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Modelling the adoption of HYV technology in developing economies may be effectively prosecuted at the micro-level in a non-separable, decision-theoretic system. The degree of adoption of high-yielding varieties of rice can be incorporated into the household decision framework and account can be taken of imperfections in labour and commodity markets. Despite the gap between theory and practice, an embryonic empirical model is implemented using survey data from Orissa, India to appraise the effectiveness of a range of agricultural policies on farm-family welfare, farm output, marketed surplus of food and rural employment.

1. Introduction

With the introduction of high-yielding crop varieties, the adoption of the new seed-fertiliser technology was accorded primary importance in the development strategies of most agrarian economies. Their governments have pursued an array of policies embodying the promotion, dissemination and adoption of the new technology. While a degree of success has been achieved, the relative effectiveness and implications of the policies are not clearly understood. This paper offers a contribution to improved understanding through a development of the theory of the semi-subsistence agricultural household, which helps to explain input-output relationships, commodity demand and labour supply. An extension of the theory also accounts for the behaviour of the farm household with respect to the adoption of new technology.

The contribution to theory is limited here by a need to focus on the empirical component of our research. However, a simple yet significant modification is suggested as an amendment to household production theory.[1] A case is made to endogenise the prices of inputs and outputs for which no markets exist. The degree of adoption of high-yielding varieties of rice has been incorporated into the standard model of household production as an endogenous variable in the household decision-making process.

In an effort to maintain consistency between the theory and the empirical model, discussion in this paper is confined to the neo-classical tradition. No attention is given to approaches suggested in evolutionary economics (Witt 1993, Tool 1988) or socio-economics (Etzioni and Lawrence 1991), which to an extent bear on the issues of household behaviour and technology adoption.

Within the neoclassical framework, the main focus in the detailed specification of the model was to use concepts and definitions of variables which have close empirical counterparts and are readily quantifiable. Although this has led to a somewhat unorthodox specification, its virtues appear to outweigh the costs.

The proposed model is described in part 2, and estimated in part 3. In part 4 the model is used to evaluate some commonly pursued policy measures. Part 5 contains the main conclusions and an outline of the scope for extension and further application of the model.

2. The Empirical Model

The first relationship important in characterising farm households in developing countries is the farm output function which may be written as:

$$q_p = q + q_m = F(l_{fs}, l_{hd}, C_f, \pi; x_i) , \qquad (2.1)$$

where q_p is the level of production; q is the level of consumption; q_m is the marketed surplus; l_{fs}, l_{hd} are labour supply and hired labour demand, C_f repre-

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[1] See Fleming and Hardaker (this volume) and Pradhan (1991) for accounts of the historical development of this theory.

sents the cash inputs, π is the extent of new technology adoption as measured by the proportion of land allocated to the new technology and x_i are other relevant exogenous variables. Note that F stands for the output function which is different from the concept of a production function. This is because the production function refers to a given technology while F is a result of combining two separate technologies. The detailed specification of this equation is pursued in Pradhan and Quilkey (1985).

The second important relationship is a utility function:

$$U = U[q,M, l_{fs}(s_i), l_{ms}(s_j), C_f(s_k)] \ , \qquad (2.2)$$

where an additional commodity M is incorporated to take account of all other consumption goods besides the subsistence good which is produced and consumed by the farm households, and s_i, s_j and s_k are i,j and k specifications of variables associated respectively with on-farm labour supply, l_{fs}, off-farm (market) labour supply, l_{ms}, and cash inputs used in farm activities, C_f. No distinction is made as to the sources of C_f which may be funded by borrowing or 'own cash' generated from liquid assets. Lending activities are assumed not to be important in the empirical context.

The specification variables, in effect, represent the sources of resource endowments, their allocations and product characteristics of relevant endogenous variables. By definition, these characteristics are exogenous variables which determine the values of their respective endogenous variables by mechanisms other than those explained by the current model. However, it is possible to identify reasonably well what these specification variables are in particular contexts.

The variables s_i and s_j may stand for such factors as family size and composition, which largely account for variation in the time endowments among farm households. Family size and composition are considered exogenous variables since they determine, without themselves being determined by, current decision-related variables such as on-farm and off-farm labour supply. Similarly, specification variables s_k accompanying cash inputs are likely to be asset and liquidity related variables such as income and wealth, and credit market related variables such as interest rates and accessibility to sources of credit.

Finally, the third important relationship is a real balance constraint that integrates the production and consumption sectors of the farm household, defined as:

$$p_s q_m + y_n + w_m l_{ms} - w_f l_{hd} - M - C_f - V = 0, \quad (2.3)$$

where p_s is the sale price of marketed surplus q_m of farm produce (rice), w_f and w_m are the on-farm and off-farm wage rates, y_n is nominal unearned income, M is the market value of non-rice consumption commodities, C_f is the use of cash inputs in the farm-firm, and V is the saving of cash that may be carried over from year to year.

The empirical optimisation problem of a semi-subsistence agricultural household implies maximising the utility function (2.2) subject to the output function (2.1) and the cash-flow identity (2.3).

To derive the empirical model, the constrained optimisation solution technique may be applied. Instead of the familiar case of a single linear constraint, here there are two constraints, one of which is non-linear. However, the general methodology applies, yielding the Lagrangian function:

$$L = U[q,M,l_{fs}(s_i), l_{ms}(s_j), C_f(s_k)] -$$

$$\lambda_1[q + q_m - F(l_{fs}, l_{hd}, C_f, \pi; x_i)] -$$

$$\lambda_2(p_s q_m + y_n + w_m l_{ms} - w_f l_{hd} - M - C_f - V), \quad (2.4)$$

where λ_1 and λ_2 are Lagrangian unknowns.

By differentiating (2.4) partially with respect to the unknown variables q, M, l_{fs}, l_{ms}, C_f, q_m, l_{hd}, π, λ_1 and λ_2, the following first order conditions are obtained:

$$L_q = U_q - \lambda_1 = 0 \ , \qquad (2.5)$$

$$L_M = U_M + \lambda_2 = 0 \ , \qquad (2.6)$$

$$L_{lfs} = U_{lfs} + \lambda_1 F_{lfs} = 0 \ , \qquad (2.7)$$

$$L_{lms} = U_{lms} - \lambda_2 w_m = 0 \ , \qquad (2.8)$$

$$L_{Cf} = U_{Cf} + \lambda_1 F_{Cf} + \lambda_2 = 0 \ , \quad (2.9)$$

$$L_{lhd} = \lambda_1 F_{lhd} + \lambda_2 w_f = 0 \ , \quad (2.10)$$

$$L_{\pi} = \lambda_1 F_{\pi} = 0 \ , \quad (2.11)$$

$$L_{qm} = -\lambda_1 - \lambda_2 p_s = 0 \ , \quad (2.12)$$

$$L_{\lambda 1} = -(q + q_m) + F(l_{fs}, l_{hd}, C_f, \pi; x_i) = 0 \ , \quad (2.13)$$

and $L_{\lambda 2} = -(p_s q_m + y_n + w_m l_{ms} - w_f l_{hd} - M - C_f - V) = 0.$ (2.14)

where the subscripted L's, U's and F's are partial derivatives of the relevant functions with respect to the indicated subscript variables.

In principle, the solution of the first-order conditions (2.5) through (2.14) would yield the relevant behavioural equations and the equilibrium values of λ_1 and λ_2 in reduced form. In practice, however, there are two reasons why a general analysis of the reduced-form behavioural equations through their derivation from (2.4) poses formidable difficulties (Deaton and Muelbauer 1980). The utility and output functions involved in equations (2.5) through (2.14) are typically nonlinear in nature, at least in variables if not in parameters. Moreover, accurate specification of U and F with respect to the variables to be included and the functional forms to be used is essential to the derivation of sensible reduced-form equations.

To overcome these difficulties, a simple linear utility function is generally assumed to exist in applied work (Stone 1954). However, this approach has problems. First, errors in specification of the unknown U and F extend to the derived reduced-form equations. Second, errors may be exacerbated particularly when U and F are nonlinear, so that application of a Taylor's series approximation would almost always be required for the solution of the first-order conditions.

In view of the above problems, the method of prior specification and reduced-form equations, despite its theoretical merit, is not followed here. Instead, attention is paid to the specification of structural relations directly, rather than the solution of first-order conditions. Because they provide more information than the reduced form, these structural relations are likely to retain more economic meaning than the reduced-form equations.

Structural relations of interest may be derived from the first-order conditions in the following way. The values of λ_1 and λ_2 are defined in terms of marginal utilities of the subsistence good and all other consumption goods in equations (2.5) and (2.6). These can also be interpreted as the prices of the two goods concerned. While λ_1 refers to the utility value of a physical entity, the subsistence good produced and consumed at home, λ_2 is the utility value of a monetary unit, the rupee value of other consumption goods. Although, in principle, either λ_1 or λ_2 could be chosen as a numeraire, λ_1 has been chosen since, by definition, supply (production) of and demand for (consumption of) q are equal, so that λ_1 represents the equilibrium value. Moreover, the study is concerned with the behaviour of subsistence and semi-subsistence farmers rather than commercial units.

From equation (2.5) which provides the linkage between the consumption sector (the farm family) and the production sector (the farm-firm) of the farm household,

$$\lambda_1 = U_q \ . \quad (2.15)$$

Using the value of the numeraire λ_1 from (2.15), the relative prices of other consumption goods can be obtained from the linkage equation (2.12) between the real and nominal sectors as:

$$\lambda_2 = -(\lambda_1 / P_s) = -(U_q / P_s) \ . \quad (2.16)$$

The Lagrangian unknowns can now be removed from the rest of the first-order system of equations by using their values from (2.15) and (2.16). The resulting system of equations defined in implicit form may be treated as the structural relations of the farm household model.

It seems natural to name the transformed first-order conditions after the variables with respect to which the Lagrangian function is differentiated. Thus, the transformed first-order condition (2.6) written as:

$$U_M - (U_q / P_s) = 0 \ , \quad (2.17)$$

may be called the **'other consumption goods function'**. It can be traced back to partial differentiation of L with respect to other consumption goods, M. Similarly, equations (2.7) through (2.11) may be transformed into the implicit **family labour supply equation**:

$$L_{lfs} + U_q F_{lfs} = 0 \ , \qquad (2.18)$$

the off-farm labour supply equation:

$$L_{lms} + (U_q / P_s)\, w_m = 0 \ , \qquad (2.19)$$

a cash-input function:

$$U_{Cf} + U_q F_{Cf} - (U_q / P_s) = 0 \ , \qquad (2.20)$$

a hired-labour demand equation:

$$U_q F_{lhd} - (U_q / P_s)\, w_f = 0 \ , \qquad (2.21)$$

and a rice-technology adoption equation:

$$U_q F_\pi = 0 \qquad (2.22)$$

respectively. To measure the output equation (2.13), the variable representing total production q_p is used in place of $(q + q_m)$ so that **the total output equation is:**

$$q_p = F(l_{fs}, l_{hd}, C_f, \pi; x_i) \ . \qquad (2.23)$$

The equations (2.17) through (2.23) along with the identities, **the output and disposal identity** :

$$q_p = q + q_m \ , \qquad (2.24)$$

and **the real balance identity:**

$$p_s q_m + y_n + w_m l_{ms} - w_f l_{hd} - M - C_f - V = 0, \qquad (2.25)$$

constitute the structural farm household model consisting of a system of nine equations in nine endogenous variables.

3. Specification of the Empirical Model

Application of the model for the measurement period - in this instance one crop year - entails estimation of the parameters of seven behavioural equations. These equations are in implicit form and are not readily estimable. Several aspects of the specification problem need to be resolved before the model can be estimated. These include:

(a) specification of individual equations in explicit form, including deciding which explanatory variables are to appear in each estimating equation;
(b) measurement of variables since some of the variables may not have direct empirical counterparts;
(c) specification of the functional form of individual equations; and
(d) prediction of the signs and magnitudes of the coefficients in each equation.

To specify the behavioural equations (2.17) through (2.23) in explicit form, the standard normalisation rule is applied. Each equation is normalised with respect to the endogenous variable which it is designed to explain. For example, the farm-output function (2.23) is normalised with respect to the output variable; the family labour supply equation (2.18) is normalised with respect to the family labour supply variable and so on. Some econometricians agree on the existence of such normalisation rules and on their existence naturally (Fisher 1970).

Information to identify the right-hand side explanatory variables in each structural equation is generally imperfect. The knowledge that each endogenous variable in a simultaneous equation system is jointly determined by all predetermined variables provides little help in the specification of structural equations. It is necessary to turn to intuition, experience and, in particular, the structural linkages in the model to specify the explanatory variables in each structural equation.

Such specification is not entirely *ad hoc*. The structural linkages, and the specification variables referred to earlier, hold the key to a great deal of correct specification. For example, by virtue of the structural linkage equation (2.18), the family labour supply equation is likely to be affected by other variables which appear in the utility function and the output function. Similarly, specification variables such as family size and composition, through their effect on time endowment, are most likely to explain family labour supply behaviour.

3.1 Estimation of the Empirical Model

In this section, the substantive results are presented employing data from farm households in Orissa, India (Pradhan 1991). The three-stage least-squares estimates along with the associated diagnostics are presented below in equations 3.1 through 3.7, where the variables and test statistics for each equation are as defined in Tables A1 through A7 in the Appendix, respectively. The results show that, as postulated in the theoretical model, none of the behavioural equations could be treated as independent of the rest of the equations in the model. This is evident from the finding that at least one other endogenous variable was found to provide statistically-significant explanations for the dependent variable of every estimating equation of the model.

A large number of factors (35) are shown to help explain the rate of adoption of high yielding varieties (HYV) of rice in this study. Many of these stimuli and inhibitors affect the technology-adoption behaviour of farmers indirectly through other decision variables. The results suggest that the single-equation method of estimating an unrestricted reduced-form equation to explain the adoption behaviour of farmers is likely to be misleading. When decisions are interdependent this method may lead researchers and policy makers to ignore many relevant determinants of technology adoption. It may also lead to misperception of the directional effect of some of the explanatory variables on technology adoption.

3.2 Interpretation of the Estimated Model

In view of the primary concern of the study with the adoption of 'new technology' and the associated behaviour of farm households, interpretation of the adoption equation (PMVRA) is undertaken first. The preferred estimate of the structural equation for the adoption of new rice technology was:

$$\begin{aligned} PMVRA = &\underset{(2.76)}{45.357} - \underset{(-5.94)}{0.0772FLKR^{***}} + \underset{(2.58)}{0.0295HLKR^{***}} + \underset{(3.10)}{0.280CCER^{***}} + \underset{(0.04)}{0.129RYD} - \underset{(-1.44)}{2.042RSDD^{*}} \\ &- \underset{(-1.43)}{0.0891PON^{*}} + \underset{(1.13)}{0.043PSPR} - \underset{(-1.83)}{0.081PBPR^{*}} + \underset{(3.11)}{0.127POIA^{***}} + \underset{(1.58)}{0.560EDLDM^{*}} + \underset{(7.21)}{6.410EXMV^{***}} \\ &- \underset{(-4.18)}{0.326EXMV2^{***}} + \underset{(3.02)}{0.0225EXPO^{***}} \end{aligned}$$

$$\bar{R}^2 = 0.71,\ F_{13,266} = 54.07^{***},\ RMSE = 17.37,\ U = 0.188,\ U^M = 0,\ U^S = 0.07 \qquad (3.1)$$

In all equations, the figures in parentheses are calculated t values, * denotes significant at the 10 per cent level, ** denotes significant at the 5 per cent level and *** denotes significant at the 1 per cent level. The summary statistics $\bar{R}^2$ and F are from the OLS equations. Other statistics are from the 3SLS equations. It is apparent from these results that the extent of adoption of HVY rice is affected by some variables that are exogenous to the farmers' decision process, as well as to others that are endogenous. It is estimated that, if a farm family could afford to hire 100 man days of labour for growing rice (HLKR), it would increase the allocation of land to HYV rice by 2.95 per cent. Similarly, a family's decision to spend 1000 rupees on market-purchased inputs (CCER) was found to be associated with allocation of 2.8 per cent of rice land to the new technology. From the negative coefficient of -0.0772 for the on-farm family labour supply (FLKR), it may be inferred that agricultural households would intensify technology adoption if the new technology is profitable enough to give the farm family more leisure.

Characteristics specific to the new technology were also found to be important determinants of the extent of adoption. Specifically, yield variability of HYV rice relative to traditional varieties (RSDD) was found to be a significant inhibitor of adoption. It may be inferred that research to reduce yield variability of HYV rice, perhaps through development of drought, flood, and insect and pest resistance, is essential for the successful promotion of the technology. The better performance of HYVs compared with the traditional varieties (RYD) was not found to be a stimulant to adoption of the new technology.

Stimuli for the adoption of HYV rice, which impinge on infrastructural development and institutional change, were percentage of irrigated rice land (POIA), experience in HYV rice (EXMV), and educational attainment of the decision maker (EDLDM). The rate of technology adoption was found to be increased by more than half a percentage point (0.56) for one year of additional schooling by the decision maker. This result is similar to that obtained by Chaudhri (1979). Experience in the production of HYV rice (EXMV) was by far the most important stimulus for adoption. It was found that the farmer's experience with HYV rice tended to increase the adoption rate, but at a decreasing rate. It was found also that the direct effect (which can be drawn from the adoption equation alone) of one year of 'hands-on' experience in HYV rice, perhaps through field-demonstrations presented by agricultural extension officers, would induce the non-adopter farmer to devote more than 6 per cent of his land to the new technology. The positive-interaction effect of experience in HYV (EXMV) and the extent of farm irrigation facilities (EXPO) on adoption rate supports the view that experience (EXMV) and the availability of irrigation facilities (POIA) are likely to be synergistic in their effects.

The degree of adoption of HYV rice was also influenced by the input and output prices. The price of nitrogenous fertilizer (PON) had a significant negative effect on the rate of technology adoption. While the selling price of rice (PSPR) had a positive but insignificant influence, the buying price of rice (PBPR) was found to be a significant inhibitor of technology adoption.

It is clear from both theoretical and empirical models that farm households' decisions on technology adoption are not independent of other decisions about on-farm labour supply (FLKR), off-farm labour supply (OFLS), hired labour demand (HLKR), level of production of rice (TRO), home consumption of rice (HRC), consumption of market purchased goods (TNFC), marketed surplus of rice (TMRS) or amount of cash used to buy factors of production (CCER) in the market. In each of the structural equations of the estimated model, at least one of the above endogenous variables appeared as a significant explanatory variable. For example, the on-farm labour supply (FLKR) of the farm household affected, and was affected by, the household's decision about the amount of labour hired (HLKR) for the production of rice on the farm, the degree of adoption of new technology (PMVRA) and the level of use of modern inputs (CCER). These variables were found to appear on the right-hand side of the on-farm labour supply equation, with statistically significant coefficients, indicating that these variables contribute to the explanation of the on-farm labour supply in semi-substance agriculture.

The estimated on-farm labour supply equation (FLKR) was:

$$\begin{aligned} FLKR = \; & \underset{(2.36)}{56.604^{***}} - \underset{(-1.38)}{1.307OFFWR^{*}} - \underset{(-9.08)}{1.138HLKR^{***}} + \underset{(6.65)}{3.28CCER^{***}} - \underset{(-2.13)}{0.568PMVRA^{***}} \\ & + \underset{(2.95)}{5.587TNFB^{***}} - \underset{(-1.38)}{9.943PDA^{*}} + \underset{(10.54)}{46.554OKRA^{***}} + \underset{(1.12)}{0.277OKRA2} - \underset{(-1.08)}{0.244VMSC} \\ & + \underset{(1.88)}{0.233POIA^{**}} - \underset{(-1.75)}{25.823PRFR^{**}} \end{aligned}$$

$$\bar{R}^2 = 0.50,\ F_{11,268} = 25.60^{***},\ RMSE = 84.22,\ U = 0.26,\ U^M = 0.0,\ U^S = 0.0 \qquad (3.2)$$

From this equation, it can be inferred that a farm household's decision to hire one more man-day of labour (HLKR) was accompanied by the withdrawal of 1.138 man-days of family labour from the production of rice. Similarly, a family intending to inject 100 rupees worth of purchased inputs into rice production (CCER) would decide to use 3.28 additional man-days of family labour. The amount of on-farm family labour supply by agricultural households was found to increase with an increase in family size (TNFB), farm size (OKRA), and the extent of irrigation facilities on the farm (POIA). The percentage of dependants in the family (PDA), the fertiliser/rice price ratio (PRFR), and the off-farm wage rate (OFFWR) all tended to reduce the on-farm labour supply from farm families.

The estimated hired labour equation (HLKR) was:

$$\begin{aligned} HLKR = \; & \underset{(0.42)}{10.928} - \underset{(-8.88)}{0.504FLKR^{***}} + \underset{(2.40)}{0.449PMVRA^{***}} + \underset{(3.16)}{0.0126TNFC^{***}} + \underset{(3.54)}{1.940CCER^{***}} - \underset{(-1.91)}{0.049OFLS^{**}} \\ & + \underset{(0.60)}{0.354HRC} + \underset{(5.33)}{22.259OKRA^{***}} + \underset{(4.39)}{0.8110KRA2^{***}} - \underset{(-0.33)}{0.670CNFMW} + \underset{(0.95)}{0.105PSPR}. \end{aligned}$$

$$\bar{R}^2 = 0.84, \; F_{10,259} = 148.02^{***}, \; RMSE = 65.02, \; U = 0.18, \; U^M = 0, \; U^S = 0.01 \qquad (3.3)$$

In this equation the quantity of labour hired for cultivation of rice appears to be largely determined by farm size (OKRA) and decision variables such as the amount of cash used (CCER), non-food consumption (TNFC), off-farm labour supply (OFLS) and the degree of technology adoption (PMVRA). Price variables such as the on-farm wage rate (CNFMW) and selling price of rice (PSPR) had no significant influence on the amount of labour hired by the farm household.

The estimated structural equation for the off-farm labour supply (OFLS) was:

$$\begin{aligned} OFLS = \; & \underset{(5.06)}{455.211^{***}} + \underset{(0.11)}{0.141CCER} + \underset{(0.05)}{0.0491TMRS} + \underset{(5.42)}{50.121TNFB^{***}} + \underset{(8.25)}{0.0497OTI^{***}} - \underset{(-0.08)}{0.877VHMA} \\ & - \underset{(-4.86)}{11.443HRC^{***}} - \underset{(-4.61)}{15.246OFFWR^{***}} - \underset{(-2.38)}{61.528PDA^{***}} - \underset{(-3.40)}{104.452DC1^{***}} - \underset{(-1.01)}{0.430PSPR}. \end{aligned}$$

$$\bar{R}^2 = 0.35, \; F_{10,269} = 16.28^{***}, \; RMSE = 200.80, \; U = 0.27, \; U^M = 0, \; U^S = 0.11 \qquad (3.4)$$

The agricultural household's off-farm labour supply behaviour was greatly influenced by market opportunities, family size (TNFB) and composition (PDA), and income (OTI). Increases in family size (TNFB) and asset income (OTI) tended to increase the size of the off-farm labour supply. On the other hand, the off-farm wage rate (OFFWR) and percentage of dependants (PDA) reduced the sale of labour in the market. Caste of the farm family (DC1) also had considerable influence on off-farm labour supply. It was found that higher caste families offered much less off-farm work than lower caste households. As the agricultural household consumed more rice in the family, a sign of a relatively rich family, off-farm labour supply declined.

The estimated cash-input use (CCER) equation was:

$$CCER = 2.554 + 0.0381FLKR^{***} + 0.0110FLS - 0.2266HRC^{***} + 0.0012OTI^{***} + 0.0580PMVRA^{**}$$
(0.83) (3.89) (0.23) (-2.42) (3.83) (1.66)

$$- 0.0808RI^{**} + 0.0009LLFF^{***} - 0.0615CAT^{**} + 0.0367HLKR^{***} + 0.0838WLTH^{***} + 0.266ANU^{***}$$
(-1.64) (3.07) (-1.71) (3.97) (4.73) (3.34)

$$\bar{R}^2 = 0.64,\ F_{11,268} = 45.86^{***},\ RMSE = 11.29,\ U = 0.23,\ U^M = 0.0,\ U^S = 0.09 \quad (3.5)$$

The farm household's decision to use cash inputs such as fertilisers and chemicals in rice production was governed by its labour supply, home consumption and rice technology adoption behaviour. Consumption of rice (HRC) and cash use in farming were found to be negatively related. The farm family's liquidity (LLFF) increased the use of cash inputs in cultivation while interest rate (RI) and credit acquisition time (CAT) reduced it. Income (OTI) and wealth (WLTH) of the family tended to increase the use of cash in farming.

The estimated farm output equation (TRO) was :

$$TRO = -7.250^{***} + 0.122FLKR^{***} - 0.0005FLKR2^{***} + 0.0297HLKR^{***} + 0.160PMVRA^{***} + 0.375CCER^{*}$$
(-3.08) (5.37) (-3.44) (2.35) (2.61) (1.49)

$$+ 0.0046CCER2^{***} + 0.0083VDAN^{***} + 0.0824APU^{***} - 0.0001APU2^{***} + 0.052POIA^{**}$$
(2.45) (5.60) (8.02) (-2.90) (1.89)

$$\bar{R}^2 = 0.78,\ F_{10,269} = 99.53^{***},\ RMSE = 14.11,\ U = 0.18,\ U^M = 0.0,\ U^S = 0.02 \quad (3.6)$$

This equation indicates that family labour (FLKR) was more productive than hired labour (HLKR) in rice production. Indeed, it was found that family labour is at least four times more productive than hired labour on account of their direct contribution to output at low levels of labour use. Farm output seemed to increase at an increasing rate with cash-inputs (CCER), reflecting the very low levels of cash use in farming in the sample households. Farm supply of rice, however, increased at a decreasing rate with the use of on-farm family labour in the rice production process. This possibly reflected the relative abundance of labour and the operation of diminishing returns to labour in the farming system studied. Apart from the input usage levels, the intensity of technology adoption (PMVRA) and irrigation (POIA) also increased the level of rice production in farm firms.

The estimated structural equation for the market goods consumption (TNFC) was :

$$TNFC = 46.426 - 2.894FLKR^{***} + 101.276CCER^{***} + 0.171OTI^{***} - 0.0000012OTI2$$
(0.07) (-2.69) (13.07) (3.02) (-0.42)

$$+ 66.104HRC^{***} + 21.355TMRS^{***} - 2.251PBPR + 3.1OFFWR + 0.00021OTWL.$$
(6.17) (3.67) (-0.80) (0.16) (1.01)

$$\bar{R}^2 = 0.83,\ F_{9,270} = 157.46^{***},\ RMSE = 1377.00,\ U = 0.17,\ U^M = 0.0,\ U^S = 0.003 \quad (3.7)$$

The consumption of market purchased commodities increased with an increase in rice consumption (HRC), cash-input use in the farm-firm (CCER), marketed surplus of rice (TMRS) and non-farm income (OTI). However, consumption decreased with an increase in the farm-household's on-farm labour supply (FLKR). The purchase price of rice (PBPR) had a negative but non-significant influence on market goods consumption.

The above seven equations describe the behaviour, on average, of the farm household in an area typical of the less-monetised economies of developing countries. The model is closed by two additional equilibrium conditions to ensure that total expenditure in any planning period, including savings, just exhausts the income of the farm household. The two identities defining respectively the money income expenditure and farm output clearance equilibria are:

$$OTI + (PSPR \times TMRS) + (OFFWR \times OFLS) - (CNFMW \times HLKR) - TNFC - CCER - SAV = 0 \quad (3.8)$$

and $$HRC = TRO - TMRS \quad (3.9)$$

Since the adoption equation is embedded in a system of simultaneous equations, the farm household's technology adoption behaviour is influenced by all the predetermined variables in the model via their effects on the endogenous explanatory variables in the PMVRA equation. Further, the indirect effects of those exogenous explanatory variables in the adoption equation may augment or offset their direct effects. Consequently, the total effect of the determinants of the new technology adoption can be traced by simulation experiments or by linear approximation of the non-linear system, permitting solution by matrix inversion. In this study, policy simulation was used. For the purpose of illustration, a limited number of predetermined variables were changed parametrically and their policy consequences analysed.

4. Policy Applications

Selected policy applications of the model are illustrated here. Key results from simulation of selected single policy applications are also compared with similar results from combined policy experiments. The results are presented in Tables A8 to A12. Two additional variables have been defined. Total labour demand (TLD) is the sum of family labour (FLKR) and hired labour (HLKR) used in the farm-firm; and total labour supply (TLS) is the total of on-farm labour supply (FLKR) and off-farm labour supply (OFLS). These two additional endogenous variables facilitate a more complete appraisal of policy consequences. Policy options are analysed by solving the model with and without the proposed changes and comparing the results.

The following limitations of the approach should be mentioned. First, policy experiments were conducted with the behavioural model of a microeconomic unit, the farm household, and average responses were obtained. Therefore, for implementation of policies at the state level, an assumption similar to the 'small-country' assumption made in international trade analyses is required, while inferences about the distributional consequences of the policies for individual farmers cannot be made directly.

In addition, it is assumed that adjustment to policy change is instantaneous. The model is static in nature and ignores lags. Finally, the policy solutions are derived on the assumption that the structural coefficients are stable for all policy changes. This assumption may be reasonable for small changes in policy variables, but if violated, the magnitude of policy responses would be modified, although the directional effects are likely to remain unchanged. However, model structure and coefficients are likely to be more stable in cross-sectional studies, as in this case, than in time series models. Subject to the above, the policy solutions indicate what would happen to technology adoption and other outcomes if the proposed policies were implemented.

Several single policy and combined policy scenarios are presented in the Appendix tables. In general, for the values selected, price-income policies appear to be much less effective in promoting the adoption of new technology and increasing agricultural production than structural/institutional policies. While, with the exception of interest rate and fertiliser price policies, single policies perform better as policies to create agricultural employment; they fail in generating increased agricultural surpluses for industrial growth. Infrastructural and institutional policies, with the exception of family planning, were found to be more effective in enhancing the degree of new technology adoption, and to be better in generating agricultural surpluses, but inferior in creating agricultural employment for the landless poor. This result is not surprising, however, as multiple goals generally require as many policy instruments as there are goals in the objective function. Hence, it may be useful to consider the consequences of combined policies which may create both agricultural employment and agricultural surpluses.

Results of the combined policies of two instruments at a time indicated that the goal of generating employment opportunities within agriculture is generally difficult to meet. Technology adoption as a strategy of agricultural development and industrial growth is easier to achieve with combined policies than creating employment opportunities within agriculture. While appropriate combined price policies may achieve this goal, their effects on family welfare and agricultural development are smaller than other combined policies.

Combined policies, in general, have less impact than the sum of individual policy effects for most response variables. Setting policy targets on the basis of single policy outcomes may, therefore, be misleading. One way to handle this problem is to set the goals and targets before experimentation with the model and attempt to find a set of policy settings which satisfy these goals. However, a target-instrument approach to policy evaluation is beyond the scope of this study. Instead, a policy-scenario approach is followed, and policy outcomes are presented, leaving the choice of policies to the planners and policy makers who may be better equipped to make value judgments about the desirability of different policy goals.

5. Conclusions

The theoretical models developed explain many farm-household decisions and their relationships in diverse socio-economic and environmental conditions. These range from pure subsistence and family farming to semi-subsistence and semi-family farming, with allowance for segmented labour markets and wage differentials.

The estimated empirical model comprises the key economic relationships that are crucial for farm households' decision-making about input and output decisions, labour supply and demand relations, home consumption and marketed supply behaviour, and the issue of technology adoption. Because of the coherent nature of the estimated model, it is capable of progressive enhancement for policy evaluation.

The findings are consistent with the view that farm-household behaviour, including technology adoption, can best be analysed in a simultaneous production and consumption framework. Significant feed-back effects appear to exist in the form of important endogenous explanatory variables between the equation for technology adoption (PMVRA) and the rest of the equations of the model. In particular, farmers' decisions about the degree of adoption of the new technology (PMVRA) for rice are closely linked to their decisions regarding levels of use of family labour (FLKR), hired labour (HLKR) and cash expenditure on purchased inputs such as fertilisers and chemicals (CCER) in rice production.

The analysis of specific policy changes using the model indicated that the most commonly pursued agricultural policies are effective to some degree in promoting technology adoption and growth in agricultural output. Price-income policies, with the exception of a reduction in the price of fertiliser, were found to be relatively less effective in enhancing the rate of technology adoption and achieving other agricultural development goals than structural and institutional policies such as irrigation, education and agricultural extension programs. While price-income policies were effective, to some extent, in creating employment opportunities in agriculture, they often reduced the marketed surplus of rice. Infrastructural and institutional policies, with the exception of a 'decrease in dependants' (PDA), resulted in large increases in marketed surplus but reduced opportunities for employment in agriculture. Most agricultural policies, both single and combined policies, seemed to enhance the welfare of farm households. For most policy goals, combined policy effects were less than the sum of the individual policy effects. The dual problem of generating agricultural surpluses and creating employment opportunities requires careful selection of agricultural policies, often involving two or more instruments.

The household model presented has the potential for extension to cover multi-product problems and agriculture in high-income countries. It may also serve as a micro foundation for more aggregated models. Despite aggregation problems, the farm household model, by representing the simultaneity of production and consumption, may be viewed as a prototype macroeconomic model for those countries where peasant farming plays a significant role.

This model has allowed for the operation of a segmented labour market. Further realism can be built in by incorporating capital market imperfections. One suggestion is to include segmented capital market features such as on-farm and off-farm cash-input use, borrowed cash-input use on the farm, and differentiated interest rates. The use of cash inputs as a factor of production may be a problem but can be overcome, in principle, by taking explicit account of individual physical inputs and their prices. This is a matter of data availability and the resources necessary to be able to define, collect and analyse the data.

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TABLE A1: Parameter Estimates of the Technology Adoption (PMVRA) Equation (3.1)

Descriptive name of explanatory variables	Variable code names and goodness of fit measures	Expected directional effect	Methods of estimation		
			OLS	2SLS	3SLS
Constant term	C	?	39.231** (2.21)	41.473** (2.32)	45.357*** (2.76)
On-farm labour supply	FLKR	-	-0.0497*** (-4.30)	-0.0604*** (-4.30)	-0.0772***(-5.94)
Hired labour demand	HLKR	+	0.0333*** (3.69)	0.02** (2.26)	0.0295*** (2.68)
Cash input use (in 100 Rs)	CCER	+	0.209*** (2.63)	0.170** (1.82)	0.280*** (3.10)
Yield ratio of MV to TV	RYD	+	1.397 (0.38)	1.457 (0.40)	0.129 (0.04)
Standard deviation ratio of MV to TV	RSDD	-	-2.277* (-1.47)	-2.362* (-1.52)	-2.042* (-1.44)
Price of nitrogen	PON	-	-0.0851* (-1.33)	-0.0891* (-1.38)	-0.0891* (-1.43)
Buying price of rice	PBPR	-	-0.082** (-1.72)	-0.080** (-1.67)	-0.081** (-1.83)
Selling price of rice	PSPR	+	0.048 (1.20)	0.0473 (1.18)	0.043 (1.13)
Per cent of irrigated area	POIA	+	0.140*** (3.24)	0.145*** (3.32)	0.127*** (3.11)
Experience in MV	EXMV	+	6.865*** (7.20)	6.832*** (7.14)	6.410*** (7.21)
Education level of farm decision makers	EDLDM	+	0.623** (1.64)	0.560* (1.46)	0.560* (1.58)
Square term of experience in MV	EXMV2	-	-0.334*** (-3.95)	-0.328*** (-3.86)	-0.326*** (-4.18)
Interaction term between experience and irrigated land	EXPO	+	0.0218*** (2.72)	0.0205*** (2.54)	0.0225*** (3.02)
	Estimation fit statistics				
	R^2		0.73		
	$\bar{R}^2$		0.71		
	$F_{13,266}$		54.07***		
	D.W.		1.59	1.60	1.64
	Simulation fit statistics				
	RMSE		17.13	17.18	17.37
	U		0.186	0.186	0.188
	U^M		0.0	0.0	0.0
	U^S		0.08	0.07	0.07

NOTE: Figures in parentheses are calculated t-values *** Significant at 1 per cent ** Significant at 5 per cent
* Significant at 10 per cent

RMSE, U, U^M, and U^S stand for root mean square simulation error, Theil's inequality coefficient, bias and variance respectively

TABLE A2: Parameter Estimates for the On-farm Family Labour (FLKR) Equation (3.2)

Descriptive name of explanatory variables	Variable code name and goodness of fit measures	Expected directional effect	Methods of estimation: OLS		2SLS		3SLS	
Constant term	C	?	65.022***	(2.39)	65.022***	(2.39)	56.604***	(2.36)
Inputed off-farm wage rate	OFFWR	-	-2.455***	(-2.47)	-1.825*	(-1.57)	-1.307*	(-1.38)
Hired labour demand	HLKR	-	-0.454***	(-7.90)	-0.877***	(-6.17)	-1.138***	(-9.08)
Farm cash input use	CCER	+	0.672**	(1.92)	1.690***	(3.15)	3.28***	(6.65)
Intensity of new rice-technology adoption	PMVRA	-	-0.425**	(-2.27)	-0.447*	(-1.46)	-0.568**	(-2.13)
Total number of family members	TNFB	+	8.055***	(4.21)	6.932***	(3.26)	5.587	(2.95)
Ratio of dependents to family members	PDA	-	-14.358	(-1.69)	-13.366*	(-1.43)	-9.943*	(-1.38)
Amount of rice land in the farm	OKRA	+	38.098***	(10.00)	44.407***	(9.35)	46.554***	(10.54)
Square term of farm rice land	OKRA2	?	-0.497***	(-2.49)	0.049	(0.18)	0.277	(1.12)
Value of modern stock of capital	VMSC	-	-0.400*	(-1.55)	-0.161	(-0.55)	-0.2441	(-1.08)
Per cent of irrigated area	POIA	+	0.142	(1.22)	0.209*	(1.41)	0.223**	(1.88)
Fertilizer-rice price ratio	PRFR	-	-28.682**	(-1.90)	-26.815*	(-1.61)	-25.823**	(-1.75)
	Equation fit measures							
	R^2		0.51					
	$\bar{R}^2$		0.50					
	$F_{11,268}$		25.60***					
	D.W.		1.79		1.90		2.01	
	Simulation fit measures							
	RMSE		66.83		73.31		84.22	
	U		0.23		0.24		0.26	
	U^M		0.0		0.0		0.0	
	U^S		0.17		0.01		0.0	

NOTE: Figures in parentheses are calculated t-values
*** Significant at 1 per cent ** Significant at 5 per cent
* Significant at 10 per cent

RMSE, U, U^M, and U^S stand for root mean square simulation error, Theil's inequality coefficient, bias and variance respectively

TABLE A3: Parameter Estimates for the Hired Labour Demand (HLKR) Equation (3.3)

Descriptive name of explanatory variables	Variable code names and goodness of fit measures	Expected directional effect	Methods of estimation		
			OLS	2SLS	3SLS
Constant term	C	?	24.679 (0.87)	10.036 (0.34)	10.928 (0.42)
On-farm family labour supply	FLKR	-	-0.370*** (-7.36)	-0.202*** (-2.93)	-0.504*** (-8.88)
Per cent of new rice-technology adoption	PMVRA	+	0.0431 (0.29)	0.162 (0.79)	0.449*** (2.40)
Market goods consumption	TNFC	+	0.0129*** (5.15)	0.0196*** (4.17)	0.0126*** (3.16)
Farm cash input use (in 100 Rs.)	CCER	+	1.098*** (2.98)	0.566 (0.91)	1.940*** (3.54)
Off-farm labour supply	OFLS	-	-0.0159 (-0.90)	-0.0461*** (-1.77)	-0.0490** (-1.91)
Home rice consumption	HRC	+	-0.659* (-1.57)	-0.130 (-0.20)	0.354 (0.60)
Square term of farm rice land	OKRA2	?	0.882*** (4.84)	1.179*** (5.69)	0.811*** (4.39)
Size of farm rice land	OKRA	+	25.040*** (6.23)	14.515*** (3.00)	22.259*** (5.33)
On-farm wage rate	CNFMW	-	-4.098** (-1.70)	-4.91** (-1.88)	-0.670 (-0.33)
Rice selling price	PSPR	+	0.0665 (0.58)	-.132 (1.07)	0.105 (0.95)
	Equation fit measures				
	R^2		0.85		
	$\bar{R}^2$		0.84		
	$F_{10,259}$		148.02***		
	D.W.		1.99	2.00	2.00
	Simulation fit measures				
	RMSE		61.54	64.32	65.02
	U		0.17	0.18	0.18
	U^M		0.0	0.0	0.0
	U^S		0.04	0.03	0.01

NOTE: Figures in parentheses are calculated t-values

*** Significant at 1 per cent ** Significant at 5 per cent

* Significant at 10 per cent

RMSE, U, U^M, and U^S stand for root mean square simulation error, Theil's inequality coefficient, bias and variance respectively

TABLE A4: Parameter Estimates for the Off-farm Labour Supply (OFLS) Equation (3.4)

Descriptive name of explanatory variables	Variable code names and goodness of fit measures	Expected directional effect	Methods of estimation: OLS		2SLS		3SLS	
Constant term	C	?	294.961***	(3.78)	458.245***	(4.93)	455.211***	(5.06)
Farm cash input use (in 100 Rs)	CCER	+	1.040	(1.05)	0.383	(0.28)	0.141	(0.11)
Market supply of rice	TMRS	+	-2.406***	(-3.25)	0.803	(0.73)	0.0491	(0.05)
Total number of family members	TNFB	+	21.252***	(3.18)	57.176***	(5.99)	50.121***	(5.42)
Asset income of farm	OTI	+	0.0421***	(8.04)	0.0511***	(8.24)	0.0497***	(8.25)
Value of family home	VHMA	-	-0.0009	(-0.91)	-0.0001	(-0.10)	-0.877	(-0.08)
Home rice consumption	HRC	-	-1.858*	(-1.36)	-13.002 ***	(-5.35)	-11.443***	(-4.86)
Off-farm wage rate (imputed)	OFFWR	-	-15.104***	(-5.04)	-14.675***	(-4.31)	-15.246***	(-4.61)
Ratio of dependents to family members	PDA	-	-47.968**	(-2.06)	-65.345***	(-2.45)	-61.528***	(-2.38)
Dummy for caste (low = 0, high = 1)	DC1	-	-102.007***	(-3.69)	-103.424***	(-3.25)	-104.452***	(-3.40)
Rice selling price	PSPR	-	0.433	(1.19)	-0.525	(-1.19)	-0.430	(-1.01)
	Equation fit measures							
	R^2		0.38					
	$\bar{R}^2$		0.35					
	$F_{10,269}$		16.28***					
	D.W.		1.80		1.78		1.78	
	Simulation fit measures							
	RMSE		183.0		207.5		200.8	
	U		0.25		0.28		0.27	
	U^M		0.0		0.0		0.0	
	U^S		0.24		0.08		0.11	

NOTE: Figures in parentheses are calculated t-values
*** Significant at 1 per cent ** Significant at 5 per cent
* Significant at 10 per cent
RMSE, U, U^M, and U^S stand for root mean square simulation error, Theil's inequality coefficient, bias and variance respectively

TABLE A5: Parameter Estimates for the Cash Input Use (CCER) Equation (3.5)

Descriptive name of explanatory variables	Variable code names and goodness of fit measures	Expected directional effect	Methods of estimation: OLS		2SLS		3SLS	
Constant term	C	?	3.553*	(1.31)	3.548	(1.07)	2.554	(0.83)
On-farm family labour supply	FLKR	+	0.022***	(2.77)	0.0234**	(2.28)	0.0381***	(3.89)
Off-farm family labour supply	OFLS	+	0.0017	(0.51)	0.0048	(0.96)	0.0011	(0.23)
Home consumption of rice	HRC	-	-0.0516	(-0.74)	-0.1796**	(-1.84)	-0.2266***	(-2.42)
Asset and other income	OTI	+	0.0011***	(4.01)	0.0010***	(3.21)	0.0012***	(3.83)
Per cent of MV rice area	PMVRA	+	0.0293	(1.08)	0.0545*	(1.46)	0.0580**	(1.66)
Borrowing interest rate	RI	-	-0.1366***	(-2.59)	-0.1274***	(-2.33)	-0.0808**	(-1.64)
Liquidity level	LLFF	+	0.0012***	(3.60)	0.0010***	(3.09)	0.0009***	(3.07)
Credit acquisition time	CAT	-	-0.0605*	(-1.54)	-0.0533*	(-1.33)	-0.0615**	(-1.71)
Hired labour demand	HLKR	+	0.0191**	(2.71)	0.0343***	(3.46)	0.0367***	(3.97)
Wealth position	WLTH	+	0.0896***	(4.87)	0.0877***	(4.59)	0.0838***	(4.73)
Amount of nitrogen fertilizer used	ANU	+	0.0297***	(3.78)	0.0235***	(2.66)	0.0266***	(3.34)
	Equation fit measures							
	R^2		0.65					
	$\bar{R}^2$		0.64					
	$F_{11,268}$		45.86***					
	D.W.		1.88		1.83		1.81	
	Simulation fit measures							
	RMSE		11.0		11.16		11.29	
	U		0.23		0.23		0.23	
	U^M		0.0		0.0		0.0	
	U^S		0.11		0.09		0.09	

NOTE: Figures in parentheses are calculated t-values
*** Significant at 1 per cent ** Significant at 5 per cent
* Significant at 10 per cent
RMSE, U, U^M, and U^S stand for root mean square simulation error, Theil's inequality coefficient, bias and variance respectively

TABLE A6: Parameter Estimates for the Farm Output (TRO) Equation (3.6)

Descriptive name of explanatory variables	Variable code names and goodness of fit measures	Expected directional effect	Methods of estimation: OLS		2SLS		3SLS	
Constant term	C	?	-0.264	(-0.14)	-4.920**	(-2.03)	-7.250***	(-3.08)
On-farm family labour supply	FLKR	+	0.0418***	(3.21)	0.121***	(5.12)	0.122***	(5.37)
Hired labour demand	HLKR	+	0.0294***	(3.47)	0.0261**	(1.98)	0.0297***	(2.35)
Per cent of MV area	PMVRA	+	0.0095	(0.26)	0.120**	(1.88)	0.160***	(2.61)
Cash input use (in 100 Rs)	CCER	+	0.1148	(0.92)	0.337*	(1.28)	0.375*	(1.49)
Value of animal power	VDAN	+	0.0081***	(6.49)	0.0081***	(5.15)	0.0083***	(5.60)
Amount of fertilizer square term	APU2	?	-0.0001	(-2.98)	-0.0001***	(-3.02)	-0.0001***	(-2.90)
Amount of fertilizer used	APU	+	0.0806***	(8.79)	0.0805***	(7.40)	0.0824***	(8.02)
Square term of on-farm family labour	FLKR2	?	-0.0002***	(-2.38)	-0.0006***	(-4.29)	-0.0005***	(-3.44)
Per cent of irrigated area	POIA	+	0.0582***	(2.51)	0.0615**	(2.15)	0.0520**	(1.89)
Square term of cash input	CCER2	?	0.0014*	(1.39)	0.0049***	(2.51)	0.0046***	(2.45)
	Equation fit measures							
	R^2		0.79					
	$\overline{R}^2$		0.78					
	$F_{10,269}$		99.53***					
	D.W.		1.58		1.61		1.65	
	Simulation fit measures							
	RMSE		12.84		13.86		14.11	
	U		0.16		0.18		0.18	
	U^M		0.0		0.0		0.0	
	U^S		0.06		0.03		0.02	

NOTE: Figures in parentheses are calculated t-values
*** Significant at 1 per cent ** Significant at 5 per cent
* Significant at 10 per cent
RMSE, U, U^M, and U^S stand for root mean square simulation error, Theil's inequality coefficient, bias and variance respectively

TABLE A7: Parameter Estimates for the Market Goods Consumption (TNFC) Equation (3.7)

Descriptive name of explanatory variables	Variable code names and goodness of fit measures	Expected directional effect	Methods of estimation: OLS		2SLS		3SLS	
Constant term	C	?	1175.22**	(1.84)	243.693	(0.33)	46.426	(0.07)
On-farm family labour supply	FLKR	-	-0.114	(-0.13)	-1.245	(-1.11)	-2.894***	(-2.69)
Cash input use (in 100 Rs)	CCER	+	50.546***	(7.82)	77.633***	(9.40)	101.276***	(13.07)
Square term of asset and other income	OTI2	-	-0.0000015	(-0.51)	-0.0000021	(-0.67)	-0.0000012	(-0.42)
Home rice consumption	HRC	+	49.051***	(6.32)	64.666***	(5.78)	66.104***	(6.17)
Marketing supply of rice	TMRS	+	54.349***	(11.66)	31.585***	(5.16)	21.355***	(3.76)
Buying price of rice	PBPR	-	-6.708***	(-2.45)	-3.513	(-1.14)	-2.251	(-0.80)
Off-farm wage rate (imputed)	OFFWR	+	13.571	(-.68)	12.576	(0.59)	3.100	(0.16)
Asset and other income	OTI	+	0.259***	(4.47)	0.206***	(3.29)	0.171***	(3.02)
Interaction term of wealth and other income	OTWL	+	0.00026	(1.23)	0.00007	(0.32)	0.00021	(1.01)
	Equation fit measures							
	R^2		0.84					
	$\bar{R}^2$		0.83					
	$F_{9,270}$		157.46***					
	D.W.		1.82		1.80		1.79	
	Simulation fit measures							
	RMSE		1209.0		1277.0		1377.0	
	U		0.15		0.16		0.167	
	U^M		0.0		0.0		0.0	
	U^S		0.04		0.03		0.003	

NOTE: Figures in parentheses are calculated t-values
*** Significant at 1 per cent ** Significant at 5 per cent
* Significant at 10 per cent

RMSE, U, U^M, and U^S stand for root mean square simulation error, Theil's inequality coefficient, bias and variance respectively

TABLE A8: Percentage Changes in Farm Household Responses to Price-Income Policies

Farm Household's Response Variables (Policy goals)	Actual Values	Predicted Values from Basic Simulation	Price-Income Policies: 10% Decrease in Interest Rate	20% Increase in Selling Price of Rice	20% Decrease in Fertilizer Price	20% Decrease in On-farm Wage Rate	20% Decrease in Buying Price of Rice	10% Increase in Non-Farm Income
On-farm Family Labour Supply $FLKR$ [1]	122.86	122.43	0.12	0.36	10.12	-2.81	-2.38	-2.07
Hired Labour Demand $HLKR$ [1]	96.44	96.71	0.44	4.81	-5.74	2.81	1.50	2.86
Total On-farm Labour Demand TLD [1]	219.30	219.14	0.26	2.32	3.00	-0.33	-0.68	0.11
Off-farm Labour Supply $OFLS$ [1]	309.19	307.84	0.38	-6.51	-3.83	-0.86	1.29	-1.14
Total Family Labour Supply TLS [1]	432.05	430.27	0.31	-0.56	0.11	-1.41	0.25	-1.40
Farm Rice Output TRO [2]	28.90	28.87	0.13	1.24	6.15	-0.98	0.59	-0.97
Cash Input Use $CCER$ [3]	1672.05	1668.71	1.31	0.91	1.24	0.46	1.38	1.31
Non-food Consumption $TNFC$ [3]	2852.23	2854.73	0.57	1.42	2.43	0.23	3.93	2.48
Per Cent of Adoption PMVRA	34.74	34.76	0.03	1.38	3.20	0.16	3.56	0.17
Marketed Supply of Rice $TMRS$ [2]	8.16	8.01	0.76	-0.84	9.24	-6.38	6.41	-7.32
Home Consumption HRC [2]	20.74	20.86	-0.48	2.03	4.96	1.10	-1.64	1.47

1. Man Days 2. Qt (Quintals) 3. Rs (Rupees)

TABLE A9: Percentage Change in Farm Household Response to Structural/Institutional Policies in Orissa, India

Farm Household's Response Variables (Policy Goals)	Ratio of Actual to Predicted Values	Infrastructural/Institutional Policies: 20 % Increase in Farm Size	20 % Increase in Irrigation Area	Increase in Experience by 2 Years	5 Years Increase in Education	20 % Decrease in Dependants
On-farm Family Labour Supply FLKR $_1$	1.004	14.09	3.81	-2.91	-0.95	3.19
Hired Labour Demand HLKR $_1$	0.997	17.33	-2.02	-0.46	-0.16	-1.80
Total On-farm Labour Demand TLD_1	1.001	15.97	1.24	-1.83	-0.60	0.99
Off-farm Labour Supply OFLS $_1$	1.004	-0.01	-4.11	-1.17	-0.36	1.71
Total Family Labour Supply TLS $_1$	1.004	3.08	-1.87	-1.67	-0.53	2.13
Farm Rice Output TRO $_2$	1.001	6.75	7.48	2.97	0.99	1.40
Cash Input Use CCER $_3$	1.002	6.57	0.43	1.70	0.57	-0.38
Non-food Consumption TNFC $_3$	0.999	4.17	3.14	2.51	0.83	0.64
Per cent of Adoption PMVRA	0.999	-4.34	3.99	8.81	2.92	-0.27
Marketed Supply of Rice TMRS $_2$	1.019	19.60	13.08	6.72	2.29	-2.62
Home Consumption HRC $_2$	0.994	1.77	5.33	1.53	0.49	2.95

1. Man Days 2. Qt (Quintals) 3. Rs (Rupees)

TABLE A10: Joint and Interaction Effects of 20 Per Cent Increase in Selling Price of Rice and 20 Per cent Decrease in Fertiliser Price

Farm Household's Response Variables (Policy Goals)	Basic Simulation Values	Policy Simulation Values	Percentage Changes: Combined or Joint Policy (a)	Sum of Individual Policy (b)	Interaction Effects = |(a)| - |(b)|
On-farm Family Labour Supply FLKR 1	122.43	132.490	8.22	10.48	-2.26
Hired Labour Demand HLKR 1	96.71	96.919	0.22	0.93	-0.71
Total On-farm Labour Demand TLD 1	219.14	229.409	4.67	5.32	-0.65
Off-farm Labour Supply OFLS 1	307.84	277.238	-9.94	-10.34	-0.40
Total Family Labour Supply TLS 1	430.27	409.728	-4.77	-0.45	4.32
Farm Rice Output TRO 2	28.87	30.744	6.49	7.39	-0.90
Cash Input Use CCER 3	1668.71	1701.551	1.96	2.15	-0.19
Non-food Consumption TNFC 3	2854.73	2959.328	3.66	3.85	-0.19
Per Cent of Adoption PMVRA	34.76	39.530	4.77	4.58	0.19
Marketed Supply of Rice TMRS 2	8.01	8.528	6.47	8.44	-1.97
Home Consumption HRC 2	20.86	22.216	6.50	6.99	-0.49

1. Man Days 2. Qt (Quintals) 3. Rs (Rupees)

TABLE A11: Joint and Interaction Effects of 20 Per Cent Increase in Irrigated Land and 2 Years Increase in Experience in HYV Rice

Farm Household's Response Variables (Policy Goals)	Basic Simulation Values	Policy Simulation Values	Percentage Changes: Combined or Joint Policy (a)	Sum of Individual Policy (b)	Interaction Effects = |(a)| - |(b)|
On-farm Family Labour Supply $FLKR_1$	122.43	124.200	1.45	0.90	0.55
Hired Labour Demand $HLKR_1$	96.71	94.409	-2.38	-2.48	-0.10
Total On-farm Labour Demand TLD_1	219.14	218.609	-0.24	-0.59	-0.35
Off-farm Labour Supply $OFLS_1$	307.84	292.205	-5.08	-5.28	-0.20
Total Family Labour Supply TLS_1	430.27	416.405	-3.22	-3.54	-0.32
Farm Rice Output TRO_2	28.87	31.727	9.90	10.45	-0.50
Cash Input Use $CCER_3$	1668.71	1698.585	1.79	2.13	-0.34
Non-food Consumption $TNFC_3$	2854.73	3002.363	5.17	5.65	-0.48
Per Cent of Adoption PMVRA	34.76	45.870	11.11	12.80	-1.69
Marketed Supply of Rice $TMRS_2$	8.01	9.488	18.45	19.80	-1.35
Home Consumption HRC_2	20.86	22.239	6.61	6.86	-0.25

1. Man Days 2. Qt (Quintals) 3. Rs (Rupees)

TABLE A12: Joint and Interaction Effects of 20 Per Cent Increase in Irrigated Rice Land and 20 Per Cent Decrease in Fertiliser Price

Farm Household's Response Variables (Policy Goals)	Basic Simulation Values	Policy Simulation Values	Percentage Changes		
			Combined or Joint Policy (a)	Sum of Individual Policy (b)	Interaction Effects = |(a)| - |(b)|
On-farm Family Labour Supply FLKR 1	122.43	140.533	14.79	13.93	0.86
Hired Labour Demand HLKR 1	96.71	89.353	-7.69	-7.76	-0.07
Total On-farm Labour Demand TLD 1	219.14	229.886	4.90	4.24	0.66
Off-farm Labour Supply OFLS 1	307.84	284.371	-7.62	-7.94	-0.32
Total Family Labour Supply TLS 1	430.27	424.904	-1.25	-1.76	-0.51
Farm Rice Output TRO 2	28.87	32.554	12.67	13.63	-0.96
Cash Input Use CCER 3	1668.71	1687.925	1.15	1.67	-0.52
Non-food Consumption TNFC 3	2854.73	2992.552	4.83	5.57	-0.74
Per Cent of Adoption PMVRA	34.76	39.31	4.55	7.19	-2.64
Marketed Supply of Rice TMRS 2	8.01	9.631	20.24	22.32	-2.08
Home Consumption HRC 2	20.86	22.923	9.89	10.29	-0.40

1. Man Days 2. Qt (Quintals) 3. Rs (Rupees)