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A Structural Estimation for Japanese Rice Farmers

by

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Abstract

The “shadow” or “internal” wage plays a crucial role, via the “internal wage effect”, in models of agricultural households with absent or constrained off-farm wage employment. To verify its empirical relevance, parameters of the production and welfare functions are estimated for Japanese rice farmers. It is inferred from this structural estimation that their off-farm wage employment is actually constrained and that the “internal wage effect” of changes in the price of rice significantly influences their supply of rice.

*Keywords*: downward sloping supply function, internal wage, structural estimation

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Agricultural household models with absent or constrained off-farm wage employment have recently been utilized in empirical analyses of the behavior of agricultural households. It is well known that these models are non-separable in the sense that their production organization and consumption choice are to be jointly determined. This non-separability makes empirical analyses of the models more difficult than those of the separable models and the analyses have been conducted so far in two different ways.<sup>1</sup> One uses reduced forms of the demand and supply functions of labor. They are specified for estimation as linear or log-linear functions of exogenous variables relevant both to production organization and to consumption choice (e.g., Arayama; Kang and Maruyama). The other uses a semi-reduced form of the supply function of labor. In this method, the production function is estimated first to obtain the marginal revenue product of farm labor or, equivalently, the demand wage. Then the supply function of labor is specified for estimation as a log-linear function of this wage, the full income evaluated at this wage, and other relevant variables (e.g., Jacoby, Skoufias).

These efforts, however, are unable to identify crucial roles played by the "shadow" or "internal" wage<sup>2</sup> in the comparative statics analysis of the models. The internal wage is an endogenous variable equilibrating the demand for labor with its supply in the internal market within the household. Sonoda and Maruyama analyze how this wage is adjusted to changes in exogenous variables and show that responses of the other endogenous variables are decomposed into two parts.<sup>3</sup> One is the direct effect of changes in the designated exogenous variables, which coincides with the responses in the separable agricultural household model. The other is the indirect "internal wage

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<sup>1</sup> Lopez estimated various elasticities associated with the behavior of self-employed agricultural households in Canada by use of a non-separable model, but he imposed a number of strong assumptions including constant returns to scale.

<sup>2</sup> This wage is closely related to the "virtual price" of labor due to Neary and Roberts.

<sup>3</sup> Unlike Sonoda and Maruyama who directly work with the optimality conditions associated with the household's welfare maximization, Strauss defines the shadow wage by use of the profit and expenditure (full income) functions to analyze changes in the shadow wage and their effects on responses of the other variables.

effect" of changes in the internal wage caused by changes in the same exogenous variables. When this method of decomposition is applied, the response of output supply to its own price reveals an interesting possibility. Its direct effect proves to be positive, while its internal wage effect is negative under plausible assumptions. Hence, in case the former is dominated by the latter, the output supply function turns out to be downward sloping. Neither of the two conventional methods described above is able to perform this type of analysis.

This article presents a structural estimation of the output supply of Japanese rice farmers to ascertain the empirical relevance of the method proposed by Sonoda and Maruyama. To implement this estimation, we utilize the optimality conditions in the non-separable model which are formally equivalent to those in the separable model if the endogenous internal wage is substituted for the exogenous market wage. Following Jacoby and Skoufias, the production function is estimated first to obtain the internal demand wage, which is equated to the internal supply or reservation wage in equilibrium. Then parameters of the welfare function are estimated by use of a system of expenditure equations similar to those for the linear expenditure system with the internal wage being substituted for the market wage. This analysis does not assume a priori that the off-farm employment constraint is binding, but it is subject to a statistical test by comparing the estimated internal wage with the estimated market wage. If the internal wage proves to be significantly lower than the market wage, the constraint is inferred to be binding.

The following section introduces a model of the agricultural household with constrained off-farm employment and discusses the properties of the internal wage and its effects on output supply. This is followed by a structural estimation of relevant parameters of the model and discusses the implications of their estimates. The final section offers some concluding comments.

## The Model

It is assumed that a sufficient degree of consensus is observed among different members of the household so that their welfare function exists. The welfare function  $U(\cdot)$  takes on the following form:

$$(1) \quad W = U(C_1, C_2, Z; G),$$

where  $C_1$ ,  $C_2$ , and  $Z$  denote the amounts consumed of a home produced farm commodity, purchased commodities, and leisure, respectively.  $G$  represents the vector of shift factors of this function. The welfare function  $U(\cdot)$  is assumed to be well-behaved in the usual sense.

The household allocates its endowed time  $Te$  among hours of farm work,  $L_1$ , off-farm work,  $L_2$ , and leisure,  $Z$ .<sup>4</sup> The endowed time identity is

$$(2) \quad L_1 + L_2 + Z = Te.$$

The household must satisfy the budget constraint.

$$(3) \quad pC_1 + p'C_2 + wZ + S + TAX \leq M,$$

where  $p$ ,  $p'$ , and  $w$  denote the prices of a farm commodity, purchased commodities, and the market wage, respectively;  $S$  and  $TAX$  represent the amounts saved and taxed, respectively;  $M$  denotes full income (Becker) of the household defined as

$$(4) \quad M = wTe + \pi + V, \quad \pi = pX - wL_1 - qF - OC,$$

where  $X$ ,  $q$ , and  $F$  denote the amount produced of a farm commodity, the price of current inputs, and their quantity, respectively; and,  $V$  and  $OC$  represent unearned incomes and other costs, respectively, which are assumed to be exogenous.

The household is assumed to produce an amount  $X$  of a farm commodity and consume  $C_1$  ( $< X$ ) of it within the household. The amount produced,  $X$ , is bounded by the production possibility.

$$(5) \quad X \leq f(L_1, F; K, T, \psi, TT),$$

where  $K$ ,  $T$ ,  $\psi$ , and  $TT$  denote the real stock of capital, the total area planted, the intensity rate of the set-aside program imposed by the government and time trend

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<sup>4</sup> In this identity it is assumed that dependents consume all their endowed time for leisure.

interpreted as the technological level in this study, respectively. See the subsequent section on data used for details of the set-aside program.  $K$  and  $T$  are assumed to be fixed. The production function  $f(\cdot)$  is assumed to be well-behaved in the usual sense.

The household is assumed to be a price taker in all markets, and faces the problem to maximize its welfare,  $W$ , subject to the constraints (2)-(5). The Kuhn-Tucker-Lagrange conditions of optimality associated with this problem imply the following relations,

$$(6.1) \quad pf_1(L_1, F; K, T, \psi, TT) - w \leq 0,$$

$$(6.2) \quad pf_2(L_1, F; K, T, \psi, TT) - q \leq 0,$$

$$(6.3) \quad U_1(C_1, C_2, Z; G) - \lambda p \leq 0,$$

$$(6.4) \quad U_2(C_1, C_2, Z; G) - \lambda p' \leq 0,$$

$$(6.5) \quad U_3(C_1, C_2, Z; G) - \lambda w \leq 0,$$

$$(6.6) \quad -pC_1 - p'C_2 - wZ - S - TAX + M \geq 0,$$

where  $\lambda \geq 0$  denotes the Lagrange multiplier associated with the budget constraint (3),  $f_i$  and  $U_j$  respectively denote the first derivatives of the functions  $f(\cdot)$  and  $U(\cdot)$ , and the complementary slackness conditions are suppressed for simplicity. For interior solutions, (6.1), (6.3), and (6.5) imply that both the demand wage  $pf_1(\cdot)$  and the supply wage  $pU_3(\cdot)/U_1(\cdot)$  of this household should be equated to the market wage  $w$

$$(7) \quad pf_1(\cdot) = w = pU_3(\cdot)/U_1(\cdot).$$

However, Arayama and Kang and Maruyama point out that this is not the case with Japanese rice farmers since the reward to their farm labor is much lower than the wage fellow members of their households are offered in their off-farm employment. This difference in wages or marginal revenue products of labor on- and off-farm seems to be caused by the disciplinary practice (Shapiro and Stiglitz) of off-farm employers

among others.<sup>5</sup> Since monitoring workers is costly, they are inclined to offer a higher than equilibrium wage; i.e., a wage higher than the reservation wage of workers, to induce them not to shirk. If a worker is caught shirking and is fired, he will pay a penalty, which is the difference between his wage and unemployment benefits or a penalty which is between his wage and income from his self-employment in case the option of the latter is available. In case other employers follow suit, the employers' employment decreases, and unemployed or self-employed workers who want wage employment will result. If an unemployed or self-employed worker is willing to work at a lower wage, employers will not lower their wage since a lower wage does not assure them of a sufficient penalty for their workers to not shirk. Therefore, prospective workers including self-employed farmers perceive that employment open to them is constrained at the market wage. Thus,

$$(8) \quad L_2 = Te - Z - L_1 \leq L = \text{constant.}$$

The available employment on the right hand side of the above inequality need not be definitely given, it only needs to be less than the amount members of the household are willing to supply at the market wage. See the celebrated article by Shapiro and Stiglitz or its closely related version by Bulow and Summers in case the option of self-employment is available for details of the non-shirking version of the efficiency wage model.

The household is now subject to the constraint in (8) in addition to the budget constraint. The optimality conditions associated with this new problem imply the following augmented set of relations:

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<sup>5</sup> Other studies give alternative explanations for the wage differential between on- and off-farm work. Shigeno points out that elderly farmers tend to be engaged in farming to gain their satisfaction or utility from farming itself and that the reward to their farm labor is likely to be lower than the market wage. Furthermore, Mishra and Goodwin examine the supply of off-farm labor in the case where the off-farm wage is exogenously fixed while the price of farm commodity is volatile, and show that for a risk-averse farmer the expected marginal revenue product of his farm labor is higher than the off-farm wage he is offered.

$$(9) \quad w^* = w - \mu/\lambda \leq w, \quad w^* = w \quad \text{for } \mu = 0,$$

$$(10.1) \quad pf_1(L_1, F; K, T, \psi, TT) - w^* \leq 0,$$

$$(10.2) \quad pf_2(L_1, F; K, T, \psi, TT) - q \leq 0,$$

$$(10.3) \quad U_1(C_1, C_2, Z; G) - \lambda p \leq 0,$$

$$(10.4) \quad U_2(C_1, C_2, Z; G) - \lambda p' \leq 0,$$

$$(10.5) \quad U_3(C_1, C_2, Z; G) - \lambda w^* \leq 0,$$

$$(10.6) \quad -pC_1 - p'C_2 - w^*Z - S - \text{TAX} + Y \geq 0,$$

$$(10.7) \quad Z + L_1 + L - Te \geq 0,$$

where  $\mu$  denotes the Lagrange multiplier associated with the constraint (10.7), which is a rearrangement of (8).  $Y$  and  $\pi^*$  stand for the full income and the residual profit imputable to the farm production activity, respectively, evaluated at the wage  $w^*$ .

$$Y = w^*Te + (w - w^*)L + \pi^* + V, \quad \pi^* = pX - w^*L_1 - qF - OC.$$

For interior solutions, (10.1), (10.3), and (10.5) imply that

$$(11) \quad pf_1(\cdot) = w^* = pU_3(\cdot)/U_1(\cdot).$$

Thus, in the case the off-farm employment constraint binds, it is not the market wage  $w$  but the discounted wage  $w^*$  that is relevant in determining the household's organization of production and its choice of consumption. Hence the wage  $w^*$  may be appropriately referred to as the equilibrium internal wage, which equilibrates the demand for labor,  $L_1 + L_2$ , with its supply,  $Te - Z$ , within the household. See Sonoda and Maruyama for further details of the properties of this wage. The relations in (7) and (11) offer a convenient device to test whether the household's off-farm employment constraint binds or not. In case its demand or supply wage is estimated to be significantly lower than the market wage, the constraint is inferred to be binding.

The inequalities in (10.1) and (10.2) that are directly associated with the determination of production organization share the endogenous internal wage  $w^*$  with the inequalities in (10.3)-(10.7) that are directly associated with the determination of consumption choice. Hence, the system of inequalities in (10.1)-(10.7) is non-separable in the sense that the production organization and the consumption choice are to be jointly determined. Non-separability of this system has a significant impact on its



comparative statics. The "internal wage effects" inherent to the agricultural household under the constrained off-farm employment render both its supply of the commodity and its demands for factors less elastic. In extreme cases, these effects give rise to downward-sloping supply and upward-sloping demand functions.

### *Comparative Statics of Commodity Supply and the Internal Wage*

The response of commodity supply to changes in selected exogenous variables is examined in reference to the optimality conditions in (10.1)-(10.7). For the purpose of estimation to be carried out in the following section, the production and welfare functions of the following types are specified.

$$(12) \quad \ln X = \ln A + \beta_1 \ln L_1 + \beta_2 \ln F + \beta_3 \ln K + \beta_4 \ln T + \beta_5 \ln \psi + \beta_6 TT,$$

$$(13) \quad W = b_1 \ln(C_1 - a_1) + b_2 \ln(C_2 - a_2) + b_3 \ln(Z - a_3), \quad b_1 + b_2 + b_3 = 1.$$

Equation (10.7) is always satisfied when the household is in equilibrium, and can be suppressed without loss of analytical rigor, although it must be taken into consideration in case the internal wage itself is allowed to change. The formal equivalence between the optimality conditions in (10.1)-(10.6) and those for the separable model in (6.1)-(6.6) enables us to derive the "pseudo" supply function of commodity. The attributive "pseudo" is attached on the grounds that the commodity supply function includes in its arguments the endogenous internal wage as well as the exogenous market prices. Substitution of the production function in (12) into the optimality conditions in (10.1) and (10.2) in equality provides the pseudo supply function of commodity

$$(14) \quad X = A_X \{ p^{(\beta_1 + \beta_2)} w^{*(-\beta_1)} q^{(-\beta_2)} K^{\beta_3} T^{\beta_4} \psi^{\beta_5} \exp(\beta_6 TT) \}^{1/(1-\beta_1-\beta_2)},$$

where  $A_X$  denotes a constant term. Hence, for any exogenous variable  $s$ , the corresponding elasticity of the commodity supply can be expressed in the following way

$$(15) \quad \frac{\partial \ln X}{\partial \ln s} = \left. \frac{\partial \ln X}{\partial \ln s} \right|_{dw^*=0} + \frac{\partial \ln X}{\partial \ln w^*} \frac{\partial \ln w^*}{\partial \ln s}.$$

This decomposition of the elasticities in terms of the internal wage  $w^*$  follows the method proposed by Sonoda and Maruyama. The first term on the right hand side of this equation represents a direct effect of changes in the designated exogenous variable,

which coincides with the elasticity of commodity supply in the separable model. The second term represents an indirect effect, which we call the "internal wage effect", of the changes in the internal wage  $w^*$  caused by those in the same exogenous variable. The direct effects and the elasticity of  $X$  with respect to  $w^*$  are easily evaluated by use of (14). In evaluating the elasticities of commodity supply one must evaluate the elasticities  $\partial \ln w^* / \partial \ln s$  of the internal wage with respect to the designated exogenous variables. This task is carried out by solving the following equations associated with the comparative statics analysis of the optimality conditions in (10.1)-(10.7).

(16)

$$\begin{bmatrix} pf_{11} & pf_{12} & 0 & 0 & 0 & 0 & -1 \\ pf_{21} & pf_{22} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & U_{11} & U_{12} & U_{13} & -p & 0 \\ 0 & 0 & U_{21} & U_{22} & U_{23} & -p' & 0 \\ 0 & 0 & U_{31} & U_{32} & U_{33} & -w^* & -\lambda \\ 0 & 0 & -p & -p' & -w^* & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} dL_1 \\ dF \\ dC_1 \\ dC_2 \\ dZ \\ d\lambda \\ dw^* \end{bmatrix} = \begin{bmatrix} -f_1 & 0 & -pf_{13} & -pf_{14} & -pf_{15} & 0 & 0 & 0 \\ -f_2 & 1 & -pf_{23} & -pf_{24} & -pf_{25} & 0 & 0 & 0 \\ \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ y_1 & F & -pf_3 & -pf_4 & -pf_5 & C_2 & -1 & y_2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} dp \\ dq \\ dK \\ dT \\ d\psi \\ dp' \\ dV \\ dL \end{bmatrix}$$

where  $y_1 = C_1 - X$  and  $y_2 = w^* - w$ .<sup>6</sup>

Since changes in the internal wage play an important role in the comparative statics analysis of the agricultural household under constrained off-farm employment, they are more closely examined in the case where the price  $p$  of farm commodity rises. Figure 1 illustrates how the demand and supply of labor are adjusted in the "internal market for labor" within the household. The internal market consists of the demand wage (or the marginal revenue product of labor) and the supply (or reservation) wage functions of labor; i.e., the left hand and right hand sides respectively of (11) which in

<sup>6</sup> To evaluate responses of endogenous variables to changes in  $\psi$  and  $\eta$  ( $\eta$  = per area subsidy on set-aside areas), unearned incomes  $V$  are divided into the subsidy  $VS$  on set-aside areas and others  $VO$ , while the total area planted  $T$  is divided into rice paddy  $TP$  and others  $TO$  which are not subject to the set-aside program. Since  $VS = \eta\psi TP$ , the case  $dVO = dTP = 0$  implies  $dV = (\psi d\eta + \eta d\psi) TP$ .

turn states the equilibrium of this market, and the endowment in (10.7) of time of this household. Since the relevant wage in this market is the internal wage  $w^*$ , it is measured by the vertical axis in this figure.  $L_{D,i}$  and  $L_{S,i}$ , respectively, represent the demand wage and supply wage functions of labor in period  $i$  ( $i = 1,2$ ), and  $E_i$  is the point of equilibrium.  $w_i^*$ ,  $L_{1,i}$ ,  $L_{2,i}$ , and  $Z_i$  denote the internal wage and hours of farm work, off-farm work, and leisure in period  $i$ , respectively, where hours of farm work in period  $i$ ,  $L_{1,i}$ , is the sum of  $L_{1,i}^{(1)}$  and  $L_{1,i}^{(2)}$  in the figure. Since off-farm employment is constrained, the demand wage functions contain a horizontal segment of the length equal to  $L$ . From (16) the demand and supply functions in the present specifications turn out to be downward and upward sloping, respectively,

$$(17) \quad \frac{\partial L_D}{\partial w^*} = - \left( \frac{1 - \beta_2}{1 - \beta_1 - \beta_2} \right) \frac{L_1}{w^*} < 0, \quad \frac{\partial L_S}{\partial w^*} = \frac{(1 - b_3)(Z - a_3)}{w^*} > 0,$$

where  $L_D = L_1 + L_2$  and  $L_S = Te - Z$ . In the case where the price  $p$  of farm commodity rises, the household expands its demand  $L_1$  for farm labor in order to increase its supply of farm commodity as long as the internal wage remains constant at  $w_1^*$ . On the other hand, the household expands its demand for leisure due both to the substitution and income effects caused by a rise in the price of farm commodity. Hence it reduces its supply  $L_S$  of labor as long as the internal wage  $w^*$  remains constant at  $w_1^*$

$$\left. \frac{\partial L_D}{\partial p} \right|_{dw^*=0} = \frac{L_1}{(1 - \beta_1 - \beta_2)p} > 0, \quad \left. \frac{\partial L_S}{\partial p} \right|_{dw^*=0} = - \frac{b_3(X - a_1)}{w^*} < 0 \quad \text{for } X > C_1.$$

The demand function shifts to the right, while the supply function to the left. Consequently, the internal wage rises from  $w_1^*$  to  $w_2^*$  in Figure 1 according to

$$(18) \quad \frac{\partial w^*}{\partial p} = \frac{b_3(1 - \beta_1 - \beta_2)(X - a_1) + \beta_1 X}{(1 - b_3)(1 - \beta_1 - \beta_2)(Z - a_3) + (1 - \beta_2)L_1} > 0 \quad \text{for } X > C_1.$$

The rise in the internal wage in this instance can be thought of as reflecting the intensified "perceived scarcity of time" (see, e.g., de Janvry, Fafchamps, and Sadoulet) in this household.

The change in the internal wage is reflected by the interactions between the demand and supply wage functions of labor in the internal market and is summarized compactly in the following expression for any exogenous variable  $s$

$$\frac{\partial w^*}{\partial s} = - \left( \frac{\partial L_D}{\partial s} \Big|_{dw^*=0} - \frac{\partial L_S}{\partial s} \Big|_{dw^*=0} \right) / \left( \frac{\partial L_D}{\partial w^*} - \frac{\partial L_S}{\partial w^*} \right).$$

Thus, the change in the internal wage is determined by the ratio of the difference in shifts of the demand and supply wage functions of labor to the difference in their slopes.

The effect of the change in  $w^*$  on the response of commodity supply  $X$  is represented by the internal wage effect in (15). We continue to examine the case of a rise in the price  $p$  of farm commodity to study this effect in more detail. In the case where the production function is specified in the form presented in (12), the own price elasticity of the commodity supply is evaluated as

$$(19) \quad \frac{\partial \ln X}{\partial \ln p} = \frac{\beta_1 + \beta_2}{1 - \beta_1 - \beta_2} + \frac{-\beta_1}{1 - \beta_1 - \beta_2} \frac{\partial \ln w^*}{\partial \ln p},$$

where the elasticity  $\partial \ln w^* / \partial \ln p$  corresponds to the derivative  $\partial w^* / \partial p$  in (18). The first term on the right hand side represents the direct effect of a change in  $p$ , while the second its internal wage effect. The first term has a positive effect on the commodity supply because  $\beta_1, \beta_2 > 0$ , and  $1 - \beta_1 - \beta_2 > 0$  due to the positivity of marginal products and the concavity of the production function in (12). On the other hand, the second term has a negative sign because the positive elasticity  $\partial \ln w^* / \partial \ln p$  is multiplied by its negative coefficient. Hence the sign of the combined effects depends on the relative importance of these two effects.

Figure 2 illustrates the supply response of farm commodity to a rise in its own price.  $X(w_i^*)$  ( $i = 1, 2$ ) represents the pseudo supply function of farm commodity with the internal wage evaluated at  $w_i^*$ .  $p_i$  and  $X_i$ , respectively, represent the price and quantity supplied in period  $i$ , and  $E_i$  is the point of equilibrium which corresponds to the one in Figure 1. In the case where the price  $p$  rises from  $p_1$  to  $p_2$ , the household expands its supply of farm commodity from  $X_1$  to  $X_1'$  as long as the internal wage remains constant at  $w_1^*$ . However, the internal wage does not remain constant but rises from  $w_1^*$  to  $w_2^*$  as shown both in (18) and in Figure 1, which in turn causes the demand for farm labor to be reduced. Therefore, the household will reduce its supply of farm commodity from  $X_1'$  to  $X_2$ , reflecting the internal wage effect in (19). In the case where the internal wage effect exceeds the direct effect of a rise in the price  $p$  as shown

in Figure 2, the observed supply function of farm commodity will have a downward slope.

## Estimation and Its Results Examined

### *The Data*

Data used in this study are adapted from the *Survey of Farm Households Economy by Types of Farm Households* (FHET) and the *Statistics of Prices and Wages in Rural Areas* (PWRA) published by the Japan Ministry of Agriculture, Forestry, and Fishery and from the *Annual Report on the Consumer Price Index* (RCPI) published by the Japan Management and Coordination Agency for the period 1982-91. In each year of this period, average data for seven scales of paddy in eight domestic regions excluding Hokkaido are utilized, but these data do not constitute a complete time series-cross section because FHET misses several items of relevant information.<sup>7</sup> Hence the number of observations for our time series-cross section data amounts to 283. The patterns of preference ordering and technological structure are estimated for households of monocultural rice farmers in FHET. Price indices for current inputs and capital goods are adapted from PWRA and those for purchased commodities are adapted from RCPI.

The price  $p$  of rice is estimated by dividing the production revenue from rice (yen) by its output  $X$  (kg). The market wage  $w$  for off-farm work is estimated by dividing the sum of wages, salaries, and other compensations by the corresponding off-farm work hours  $L_2$ . The price index  $q$  of current inputs (seeds and seedlings; fertilizers; feed;

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<sup>7</sup> Only classes containing more than five households are used for estimation. Scales of paddy here refer to those of planted paddy, and scale classes 1 to 7 stand respectively for 0.5-1.0ha, 1.0-1.5ha, 1.5-2.0ha, 2.0-2.5ha, 2.5-3.0ha, 3.0-5.0ha, and 5.0ha and over. Data for households of paddy scale less than 0.5ha are not used because their output of rice does not constitute an important source of their revenue and their marketed surplus of rice amounts to about 10% of its national total.

agricultural chemicals; fuel, light, heat, and processing materials) is estimated by weighting individual prices with their respective shares in the total expenditure. The price index of capital goods (buildings; agricultural motor vehicles; agricultural implements) is similarly estimated by weighting individual prices with their respective shares in the total values of capital stock.

Then, the amount of current inputs,  $F$ , is estimated by dividing the sum of input expenditures by the corresponding price,  $q$ . The amount of real capital stock,  $K$ , is estimated similarly. The amount of rice consumed,  $C_1$ , is estimated by dividing the production revenue in excess of cash revenue from rice by the corresponding price,  $p$ . The numbers of on-farm workers,  $N_1$ , and off-farm workers,  $N_2$ , are adapted from FHET to estimate the endowed time of households at  $T_e = 16 \times 365 \times (N_1 + N_2)$ . Leisure hours,  $Z$ , are estimated by endowed time,  $T_e$ , in excess of the sum  $L_1 + L_2$  of on- and off-farm work hours. The rate of set-aside,  $\psi$ , is estimated by dividing the set-aside area by the paddy area under cultivation. Estimation of the values of other variables should be clear by their definitions.

The mean on- and off-farm work hours are estimated to be 1487.9 and 3384.2 hours per household, respectively, which constitute 30.5% and 69.5% of the mean total work hours, while their respective coefficients of variation are 45.3% and 21.7%. It is well known that off-farm work offers a higher wage than on-farm work but off-farm employers do not employ as much labor as farm households want to supply at the market wage. Hence farm households are obliged to adjust their total work hours mainly with their on-farm work, which is reflected in the higher coefficient of variation. This feature of the labor market surrounding them has also been observed by other authors including Arayama and Kang and Maruyama. These observations suggest that the off-farm employment open to Japanese rice farmers is constrained.

Finally, the implementation of the set-aside program in Japan may need some comments. In the face of mounting surplus of rice, the target rate of the Japanese set-aside program intensity is decided at the Ministry of Agriculture, Forestry, and Fishery. The program is then implemented through the administrative channel which includes

prefectural governments, municipal offices, and local communities closely connected with farm cooperatives. By the Staple Food Control Act of 1942 farmers have been deprived of practically all legal outlets for their own rice but marketing it all through the nearby cooperative. Hence, they are obliged to comply with the official target rate of set-aside in exchange for the compensatory payments. The official target rate has recently reached nearly 30% of paddy area under cultivation in spite of farmers' complaints about inadequate compensatory payments. Actually there have been some signs of change both on the part of the Ministry and farmers, but they have not yet gained their practical significance.

#### *Estimation of the Model*

Parameters of the production function are estimated first to obtain the demand wage. The production function is further specified for estimation in the following way to control time invariant unobserved factors, though the data used in this study do not constitute a complete time series-cross section,

$$(20) \quad \ln X = \ln A + \sum_{i=1}^5 \beta_i \ln X_i + \beta_6 TT + \sum_{j=1}^7 \gamma_j RD_j + \sum_{k=2}^7 \delta_k SD_k + u,$$

where  $X_i$ 's ( $i = 1 \dots 5$ ) denote  $L$ ,  $F$ ,  $K$ ,  $T$ , and  $\psi$ .  $RD_j$  ( $j = 1 \dots 7$ ) and  $SD_k$  ( $k = 2 \dots 7$ ) denote regional and scale dummies and  $u$  an error term, respectively.

Both Jacoby and Skoufias estimate the production function without imposing restrictions associated with the optimality conditions for variable inputs, which is not appropriate in the case where all of the structural parameters need to be estimated in a consistent way. In the present specification of the production function, the ratio  $qF/pX$  of the expenditure for current inputs to the production revenue should be equal to  $\beta_2$ .

$$(21) \quad qF/pX = \beta_2 + v,$$

where  $v$  denotes an error term.  $u$  and  $v$  are assumed to be independent of the error terms in consumption choice. This specification may be restrictive, so we use the following more flexible one which allows  $\beta_2$  to differ among different regions and different scales of paddy field.

$$(22) \quad \beta_2 = \varepsilon_0 + \sum_{j=1}^7 \varepsilon_j RD_j + \sum_{k=2}^7 \phi_k SD_k .$$

For the data used in this study, the number of households  $N_{jk}$  included in each class differs greatly among different regions as well as among different scales. Thus, equations (20) and (21) with the relation in (22) incorporated are estimated simultaneously by the method of three stage least squares after multiplying both sides of these equations by the square root of  $N_{jk}$ , where the variable inputs  $\ln X_1 (= \ln L_1)$  and  $\ln X_2 (= \ln F)$  are treated as endogenous. To obtain more precise estimates of  $\beta_i$ 's, dummies whose coefficients have low t-values are excluded in the final estimation. Various sets of instruments were tried, but the estimation results were similar. Hence, p-values associated with the overidentifying restrictions test are used to choose the best set of instruments, which consists of the constant, seven regional dummies, six scale dummies, the exogenous variables in the production function (K, T,  $\psi$ , and TT), and other costs OC. Furthermore, the two sets of parameters ( $\varepsilon_j$ ,  $\phi_k$ ) ( $j = 0 \dots 7$ ;  $k = 2 \dots 7$ ) which appear simultaneously in (20) and (21) were tested for equality by use of an LM test proposed by Newey and West.<sup>8</sup>

The internal wage is estimated by use of the relation  $w^* = \hat{\beta}_1 p \hat{X} / L_1$  ( $\hat{X}$  being fitted value of X) and is used to estimate parameters of the welfare function. The specification in (13) of the household welfare function and the optimality conditions in (10.3)-(10.6) in equality yield a system of three expenditure equations similar to the linear expenditure system with the internal wage  $w^*$  and the full income Y in excess of the sum of S and TAX being endogenous. Since one of the three error terms added to these equations is stochastically dependent due to the budget constraint, the following two equations are estimated by controlling the effects of the time trend and the time invariant unobserved factors,

$$(23) \quad pC_1 = a_1 p + b_1 (Y - a_1 p - a_2 p' - a_3 w^*) + \sum_{j=1}^7 c_j RD_j + \sum_{k=1}^7 d_k SD_k + \tau_1 TT + u_1,$$

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<sup>8</sup> In computing the covariance matrix of the orthogonality conditions, the error terms are assumed to be conditionally homoskedastic.



$$(24) \quad p' C_2 = a_2 p' + b_2 (Y' - a_1 p - a_2 p' - a_3 w^*) + \sum_{j=1}^7 g_j RD_j + \sum_{k=1}^7 h_k SD_k + \tau_2 TT + u_2,$$

where  $Y' = Y - S - TAX$ , and  $u_1$  and  $u_2$  are error terms. Furthermore, the number  $NF$  of household members as well as the share  $FSHARE$  of farm workers  $N_1$  in all workers  $N_1 + N_2$  are used as shift factors of the welfare function to allow for different composition of members among different households.

$$(25) \quad a_i = a_{i0} + a_{i1} NF + a_{i2} FSHARE \quad (i = 1, 2, 3).$$

Since  $w^*$  and  $Y'$  are endogenous, equations (23) and (24) with the relations (25) incorporated are estimated simultaneously by the method of nonlinear three stage least squares after multiplying both sides of these equations by the square root of  $N_{jk}$ . The best set of instruments is chosen by use of  $p$ -values associated with the overidentifying restrictions test and consists of  $p$ ,  $p'$ ,  $q$ ,  $TAX$ ,  $NF$ , and  $FSHARE$  in addition to the instruments already used to estimate parameters of the production function.

Estimated coefficients of equations (20) and (21) with the relation (22) incorporated are shown in Table 1, where estimates of the coefficients  $\gamma_j$  and  $\delta_k$  are not shown.<sup>9</sup> The LM test statistic is compared with the critical value of the  $\chi^2$  distribution with 11 degrees of freedom to show that the equality of the two sets of parameters  $(\epsilon_j, \phi_k)$  in (20) and (21) is not rejected at any reasonable level of significance. The coefficients  $\beta_1$ ,  $\beta_3$ , and  $\beta_4$  of factor inputs are positive and all of them are significant at the 10% level. The coefficient  $\beta_5$  of the rate  $\psi$  of set-aside is significantly negative, so that a rise in  $\psi$  reduces the output of rice with other things being equal. Furthermore, the relation in (22) and the estimates of parameters  $(\epsilon_j, \phi_k)$  give estimates of  $\beta_2$ , whose average and standard deviation prove to be 0.1644 and 0.0226, respectively.

The elasticity  $\beta_1$  of output with respect to farm labor plays the most important role in determining the level of the internal wage  $w^*$ . Among other authors who have estimated this elasticity for Japanese rice farmers, Shintani estimates it at 0.26 for the periods 1969-71 and 1977-79 by use of a Cobb-Douglas production function, while

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<sup>9</sup> The coefficients of determination in the first stage regressions of  $\ln X_1$  and  $\ln X_2$  on the instruments are 0.92 and 0.97, respectively.

Kusakari estimates it between 0.15-0.23 for the period 1967-82 by use of a translog production function. In the light of these estimates, the present estimate 0.25 of  $\beta_1$  seems to be reasonable.

Table 2 presents estimated coefficients of equations (23) and (24) with the relations (25) incorporated.<sup>10</sup> Most of the coefficients are statistically significant and concavity of the welfare function is satisfied at the mean values of the relevant variables. The estimated coefficients of shift factors of the welfare function indicate that an increase in the number of household members, NF, raises the household's subsistence level for all commodities, while an increase in the share of farm workers, FSHARE, has an effect of lowering the household's subsistence level.

#### *Testing the Bindingness of Off-farm Employment Constraint*

From the estimated coefficients in Table 1, the estimates of the internal wage are obtained. Their means and standard deviations along with the corresponding market wage are classified for seven scale classes and their sum in Table 3, which reveals a large discrepancy between the two wages especially for small scale classes. The existence of a large discrepancy between them suggests that the off-farm employment is severely constrained, the significance of which will be tested to verify this suggestion. Following Skoufias, the equation  $\ln w^* = a + b \ln w$  is estimated to test the joint hypothesis that  $a = 0$  and  $b = 1$ . Only OLS can be applied to this estimation because such instruments as the age of family members and their education are not available. Skoufias shows that the result of his test based on the OLS estimation is very similar to the one based on the instrumental variables estimation. Hence it can offer us some inferences, though it may involve some measurement errors. Estimation of this equation results in:

$$\ln w^* = 9.711 - 0.505 \ln w, \quad F_{\text{test}} = 1620.5,$$

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<sup>10</sup> The coefficients of determination in the first stage regressions of  $w^*$  and  $Y'$  on the instruments are 0.96 and 0.94, respectively.

where  $F$  test denotes an  $F$  statistic to test the joint hypothesis that  $a = 0$  and  $b = 1$ . This test statistic is sufficiently large to reject the null hypothesis at any reasonable level of significance.

Now, we turn to test whether the mean internal wage is significantly lower than the mean market wage. We first test the normality of the difference  $D_i = w_i - w_i^*$  ( $i = 1 \dots n$ ,  $n = 283$ ) by means of the Jarque-Bera test (see, e.g., Davidson and Mackinnon). The normalized difference between the two wages is defined as  $ND_i = (D_i - \bar{D})/s_D$ , where  $\bar{D}$  and  $s_D$  denote the sample mean and standard deviation of  $D_i$ , respectively. Then,  $\{(6n)^{-1/2} \sum_{i=1}^n ND_i^3\}^2 + \{(24n)^{-1/2} \sum_{i=1}^n (ND_i^4 - 3)\}^2$  is distributed as  $\chi^2(2)$ . This statistic is 5.658 and the corresponding p-value is 0.059 for our data, indicating that the normality of  $D_i$  is not rejected at 5% level of significance. Thus,  $D_i$  is assumed to be independently and identically distributed as  $N(\alpha, \sigma^2)$  to test the null hypothesis  $H_0: \alpha = 0$  against its alternative  $H_1: \alpha > 0$ . We can construct a test statistic  $t = n^{1/2}(\bar{D} - \alpha)/s_D$  which has a  $t$ -distribution with  $n-1$  degrees of freedom. This statistic is 38.1 under the null hypothesis for our data, indicating that  $H_0$  is rejected against  $H_1$  at any reasonable level of significance. Hence the mean of  $w^*$  proves to be significantly lower than that of  $w$ .

Since support for normality of the difference  $D$  is modest in the test above, it may be advisable to verify our result by use of other nonparametric tests, e.g., the Wilcoxon signed rank sum test. For a sufficiently large  $n$ , the test statistic  $W = \sum_{i=1}^n \varepsilon_i R_i$  is asymptotically distributed as  $N(\mu_n, \sigma_n^2)$ , where  $R_i$  is the rank of  $D_i$ ,  $\varepsilon_i = 1$  if  $D_i > 0$  and  $\varepsilon_i = 0$  otherwise, and  $\mu_n = n(n+1)/4$  and  $\sigma_n^2 = n(n+1)(2n+1)/24$ , respectively. Since  $D_i > 0$  therefore  $\varepsilon_i = 1$  for all  $i$  in our data, it is obvious that  $H_0: \alpha = 0$  is rejected against  $H_1: \alpha > 0$  at any reasonable level of significance.

Sufficient care must be taken in interpreting the result of these tests since both the internal and market wages may involve some measurement errors. However, it is not the wages themselves but the difference between them that is addressed in these tests. Therefore, it is hoped that measurement errors are offset by each other to a reasonable extent.

*Estimated Elasticities of Rice Supply and the Internal Wage with Respect to Selected Exogenous Variables*

Estimated values of the elasticities of rice supply and the internal wage for the non-separable model are evaluated at the mean values of the relevant variables in comparison with the corresponding values for the separable model in Table 4. The values for the separable model are estimated from those values for the non-separable model by setting  $dw^* = 0$  since the internal wage is identically equal to its market wage in the separable model. In determining the commodity supply of the agricultural household under constrained off-farm employment, the working of the internal labor market plays an extremely important role via the "internal wage effect". Hence the elasticities of the demand and supply of labor are examined first.

By use of the relations in (17), the elasticity of labor demand with respect to the internal wage is estimated to be  $-0.436$ , while the similar elasticity of labor supply  $0.142$  at the mean values of the relevant variables. Thus, the supply function has a relatively steep slope in the internal labor market. On the other hand, the elasticities of the internal wage with respect to  $p$  and  $L$  are estimated to be relatively high, so that changes in them can cause large shifts of the demand or supply functions of labor, or both. Actually, the magnitudes of the shifts in the demand function caused by changes in  $p$  and  $L$ ,  $L_1/(1 - \beta_1 - \beta_2)L_D$  and  $L/L_D$  evaluated in their elasticity form, respectively, are estimated to be  $0.521$  and  $0.695$ . Similarly, the magnitudes of the shifts in the supply function,  $-b_3p(X - a_1)/w^*L_S$  and  $b_3(w^* - w)L/w^*L_S$  are estimated to be  $-0.562$  and  $-0.550$ , respectively.

Responses of rice supply are examined in reference to these elasticities. Its elasticity with respect to its own price  $p$  is estimated to be  $-0.121$ , which is decomposed into the direct effect and the internal wage effect. The former proves to be  $0.708$ , while the latter is  $-0.829$ . Thus, the direct effect is dominated by the internal wage effect, so that the corresponding supply function of rice slopes downward as shown in Figure 2. Why is this internal wage effect so large for Japanese rice farmers? The associated

high elasticity of internal wage with respect to the price of rice is attributed to the relatively steep slope of their supply function of labor and to the large shifts in their demand and supply functions of labor in the internal market. Equation (17) implies that  $\partial \ln L_S / \partial \ln w^* = (1 - b_3)(Z - a_3) / (L_1 + L_2)$ , which is the "marginal propensity to work"  $(1 - b_3)$  times the ratio of "discretionary time"  $(Z - a_3)$  to the sum  $(L_1 + L_2)$  of on- and off-farm work hours. The steep slope of Japanese rice farmers' supply function of labor is caused mainly by their long work hours both on and off farm. Thus, a large remuneration is required to induce them to work longer hours. On the other hand, the large shifts both in their demand and supply functions of labor reflect the importance of the production revenue from rice, which is naturally expected because only households of monocultural rice farmers are analyzed in this study.

The elasticity of rice supply with respect to the rate  $\psi$  of set-aside is estimated to be  $-0.083$ . The internal wage effect is small in this case, but it renders the supply of rice less elastic. A relatively small absolute value of this elasticity suggests the presence of many loopholes which enable rice farmers to evade the anticipated effects of this program. Therefore, the government has to impose an extremely high rate of set-aside to attain its proposed objectives, which is actually observed. Furthermore, the elasticity of rice supply with respect to the amount of subsidy on set-aside areas,  $\eta$ , is estimated to be negligible. Hence, an isolated change in this subsidy is hardly effective. Finally, the rice supply elasticity with respect to the off-farm employment opportunities  $L$  is estimated to be  $-0.920$ , which is expected to be large since off-farm employers offer a much higher wage than the internal wage. Hence, a large reduction of rice supply will occur as the off-farm employment opportunities expand.

## Concluding Remarks

Agricultural households very often face absent or constrained off-farm wage employment for some reason or other both in developing and in developed economies. In case they do, their behavior is significantly influenced by their internal wage which equilibrates their demand with their supply of labor in excess of their off-farm employment. Hence it is very important to analyze how their internal wage is affected by changes in exogenous variables and how changes in this wage in turn affect other endogenous variables. To investigate the role of their internal wage in an empirical context, this article has attempted to estimate all the structural parameters relevant to the households of Japanese rice farmers.

Japanese rice farmers' internal wage is estimated to be significantly lower than their market wage, so that their off-farm wage employment constraint is inferred to be binding. Furthermore, the comparative statics analysis of these households suggests that the elasticity of their internal wage with respect to the price of rice is so high that their perceived scarcity of time proves to be sensitive to changes in it. This sensitivity seems to reflect the importance of their production revenue from rice growing as well as the fact that members of Japanese rice farmers work very long hours both on and off their farms. The high elasticity of the internal wage gives rise to the large internal wage effect on the supply of rice. Thus, the supply function of rice turns out to be downward sloping.

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Table 1. Estimated Coefficients of Equations (20) and (21)  
with the Relation (22) Incorporated

$\beta_1$	0.2502	(3.513)
$\beta_3$	0.0549	(1.689)
$\beta_4$	0.2840	(3.056)
$\beta_5$	-0.0781	(3.486)
$\beta_6$	0.0099	(3.556)
$\varepsilon_0$	0.1772	(45.463)
$\varepsilon_1$	-0.0339	(10.306)
$\varepsilon_2$	-0.0314	(9.559)
$\varepsilon_3$	-0.0233	(6.337)
$\varepsilon_4$	-0.0088	(2.045)
$\varepsilon_5$	-0.0201	(5.104)
$\varepsilon_7$	-0.0234	(2.536)
$\phi_2$	0.0286	(9.161)
$\phi_3$	0.0151	(4.299)
$\phi_6$	-0.0109	(1.557)
$\phi_7$	-0.0100	(2.228)
$R_X^2$	0.9997	
$R_F^2$	0.9730	
J-test	10.140	[0.428]
LM	0.122	{1.000}

Note: Some of the coefficients  $\varepsilon_i$  and  $\phi_j$  are set equal to nil in this final estimation.  $R_X^2$  and  $R_F^2$  denote the coefficients of determination for equations (20) and (21) respectively and J-test a  $\chi^2$  statistic associated with the overidentifying restrictions test. LM denotes an LM statistic to test the equality of the two sets of parameters ( $\varepsilon_j$ ,  $\phi_k$ ) in (20) and (21). Absolute values of t-statistics are shown in parentheses ( ) and the upper tail areas for  $\chi^2(10)$  and  $\chi^2(11)$  in brackets [ ] and in braces { } respectively.

Table 2. Estimated Coefficients of Equations (23) and (24)  
with the Relations (25) Incorporated

a <sub>10</sub>	-1460.2	( 1.459)
a <sub>11</sub>	561.8	( 2.354)
a <sub>12</sub>	-2501.5	( 1.925)
a <sub>20</sub>	-57989.3	( 1.935)
a <sub>21</sub>	22810.1	( 4.780)
a <sub>22</sub>	-113912.0	( 5.582)
a <sub>30</sub>	-8370.9	( 1.681)
a <sub>31</sub>	4678.2	( 3.972)
a <sub>32</sub>	-15307.6	( 2.836)
b <sub>1</sub>	0.0431	( 2.231)
b <sub>2</sub>	0.5040	( 9.076)
b <sub>3</sub>	0.4529	( 7.573)
$\tau_1$	-7888.8	( 3.647)
$\tau_2$	43096.9	( 3.755)
R <sub>1</sub> <sup>2</sup>	0.8619	
R <sub>2</sub> <sup>2</sup>	0.9915	
J-test	21.585	[ 0.119]

Note: R<sub>1</sub><sup>2</sup> and R<sub>2</sub><sup>2</sup> denote the coefficients of determination for equations (23) and (24) respectively and J-test a  $\chi^2$  statistic associated with the overidentifying restrictions test. The value of b<sub>3</sub> is estimated by use of the relation b<sub>1</sub>+b<sub>2</sub>+b<sub>3</sub> = 1. Absolute values of t-statistics are shown in parentheses ( ) and the upper tail area for  $\chi^2(15)$  in brackets [ ].

Table 3. Comparison of the Estimated Internal Wage  
with the Market Wage (Yen/hour)

Scale Class	Internal Wage	Market Wage
1	315.6 (63.2)	1481.7 (261.2)
2	415.2 (92.5)	1375.8 (223.6)
3	491.7 (86.2)	1260.0 (294.5)
4	573.5 (74.0)	1112.5 (223.9)
5	625.0 (106.1)	1069.7 (219.0)
6	708.5 (117.9)	1106.2 (192.3)
7	734.3 (74.4)	1229.1 (126.0)
All	473.3 (160.8)	1300.7 (283.7)
Minimum	207.4	725.6
Maximum	978.2	2155.2

Note: Standard deviations are shown in parentheses ( ).

Table 4. Estimated Elasticities of Rice Supply and the Internal Wage with Respect to Selected Exogenous Variables

	Non-Separable Model	Separable Model
$\partial \ln X / \partial \ln p$	-0.121	0.708
$\partial \ln X / \partial \ln q$	-0.149	-0.281
$\partial \ln X / \partial \ln K$	0.047	0.094
$\partial \ln X / \partial \ln T$	0.243	0.485
$\partial \ln X / \partial \ln \psi$	-0.083	-0.133
$\partial \ln X / \partial \ln p'$	0.251	0.000
$\partial \ln X / \partial \ln \eta$	-0.016	0.000
$\partial \ln X / \partial \ln L$	-0.920	0.000
$\partial \ln w^* / \partial \ln p$	1.941	0.000
$\partial \ln w^* / \partial \ln q$	-0.308	0.000
$\partial \ln w^* / \partial \ln K$	0.110	0.000
$\partial \ln w^* / \partial \ln T$	0.566	0.000
$\partial \ln w^* / \partial \ln \psi$	-0.117	0.000
$\partial \ln w^* / \partial \ln p'$	-0.586	0.000
$\partial \ln w^* / \partial \ln \eta$	0.038	0.000
$\partial \ln w^* / \partial \ln L$	2.153	0.000

Note: Elasticities for the separable model are estimated by setting  $dw^* = 0$ .

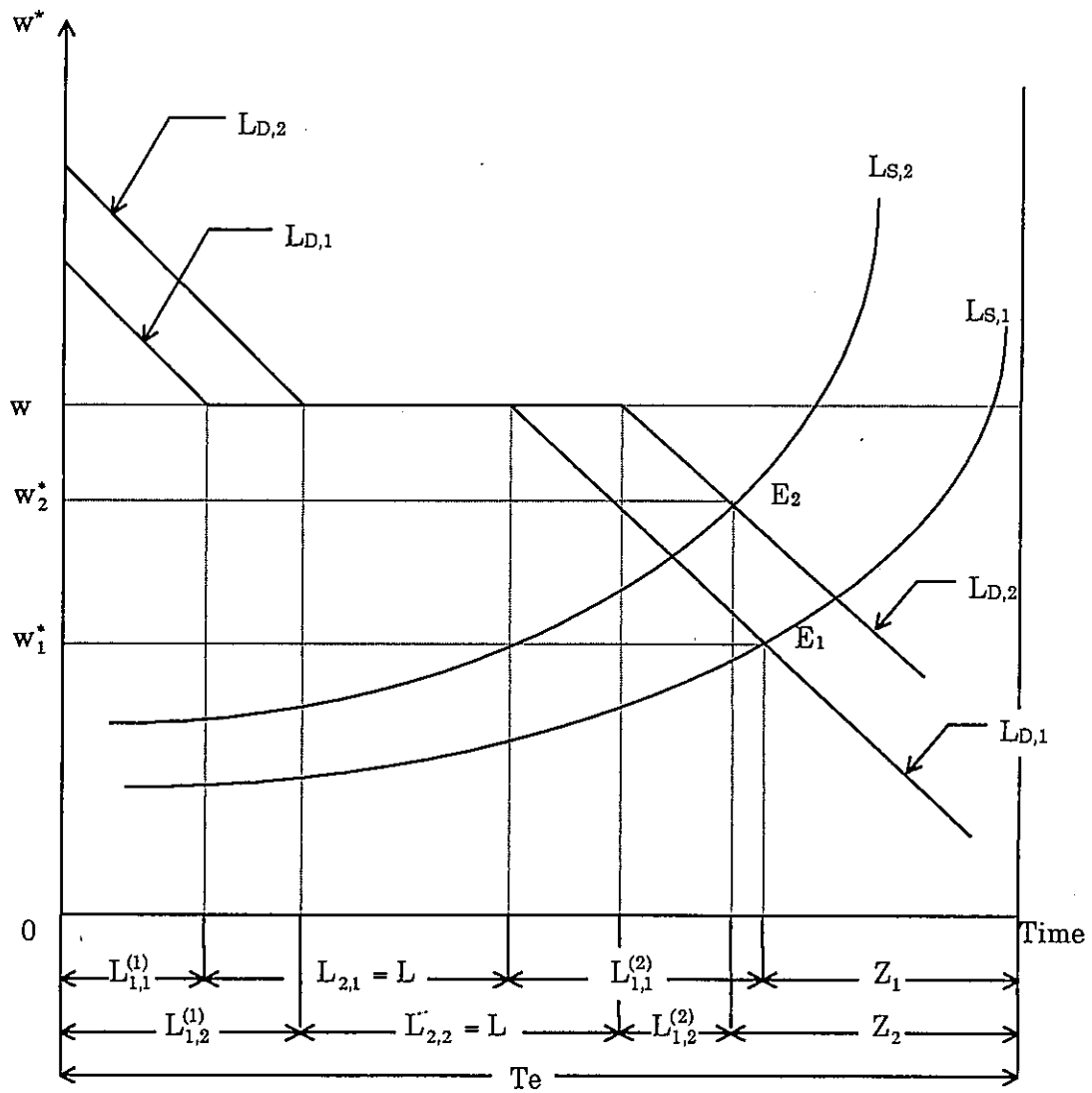


Figure 1. The internal market for labor within the household

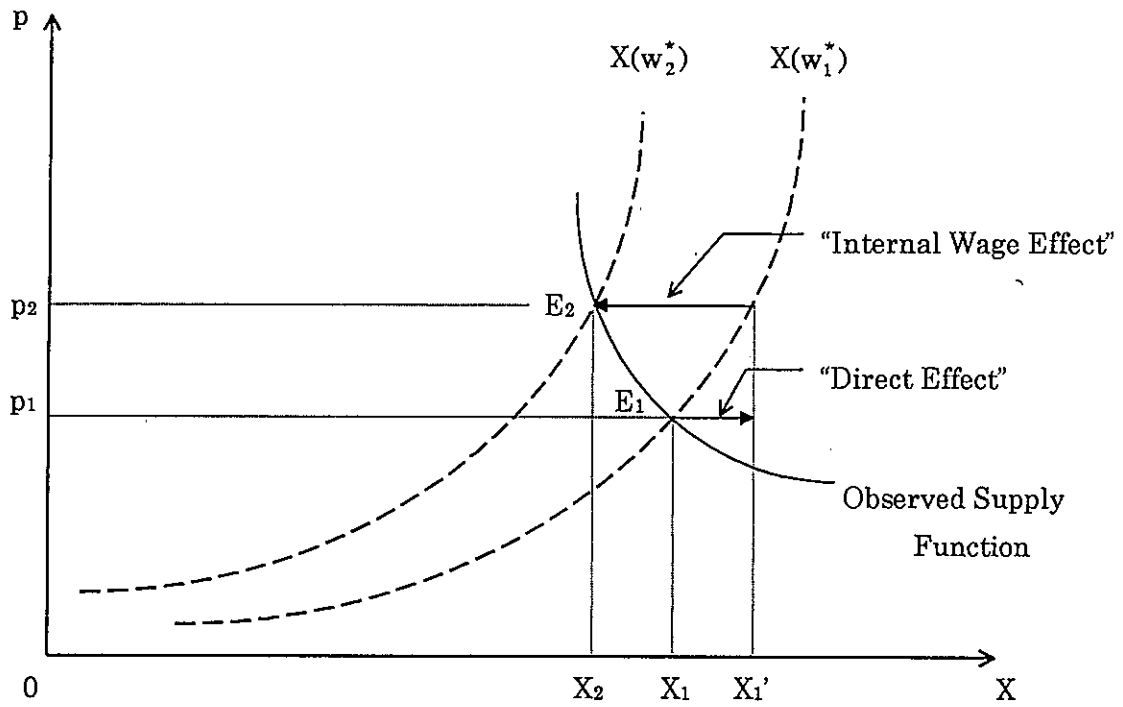


Figure 2. Response of the supply of farm commodity to a change in its price