Chapter 2

Effects of the Internal Wage on Output Supply: A Structural Estimation for Japanese Rice Farmers

2.1 Introduction

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.[1] 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, 1986; Kang and Maruyama, 1992). 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, 1993; Skoufias, 1994).

These efforts, however, are unable to identify crucial roles played by the "shadow" or "internal" wage [2] 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 (1998) 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 (see Appendix of this chapter for

[1] Lopez (1984) estimated various elasticities associated with the behavior of self-employing agricultural households in Canada by use of a non-separable model, but he imposed a number of strong assumptions including constant returns to scale.
[2] This wage is closely related to the "virtual price" of labor due to Neary and Roberts (1980).

details).[3] 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 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 chapter 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 (1998). 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 (1993) and Skoufias (1994), 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 utility 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. It is found from this analysis that the off-farm wage employment open to Japanese rice farmers is constrained in the specification of this chapter and that a large internal wage effect of changes in the price of rice gives rise to its downward-sloping supply function.

The following section introduces a model of the agricultural household with

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[3] Unlike Sonoda and Maruyama (1998) who directly work with the optimality conditions associated with the household's utility maximization, Strauss (1986) 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.

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.

2.2 The Model

The agricultural household is assumed to maximize its utility function u(c; Z) subject to some constraints, where c denotes the vector of a home produced farm commodity c_f, purchased market commodities c_m, and leisure c_l, and Z denotes the vector of shift factors of this function. The utility function u(•) is assumed to be well-behaved in the usual sense.

The household allocates its endowed time T among hours of farm work x_l, off-farm work L, and leisure, c_l.[4] The endowed time identity is

$$x_l + c_l + L = T. \tag{2.1}$$

The household must satisfy the budget constraint:

$$p_f c_f + p_m c_m + p_l c_l = M, \tag{2.2}$$

where p_i denotes the price of commodity i. Expression M denotes full income (Becker, 1965) of the household defined as

$$M \equiv p_l T + p_f x_f - p_l x_l - p_v x_v + I, \tag{2.3}$$

where x_f, p_v, x_v, and I denote the amount produced of a farm commodity, the price of current inputs, their quantity, and exogenous unearned incomes, respectively.

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

$$x_f \le f(x; K), \tag{2.4}$$

where x denotes the vector of variable inputs, x_l and x_v, and K denotes the vector of shift factors of the function f(•). The production function f(•) is assumed to be well-behaved in the usual sense.

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[4] In this identity it is assumed that dependents consume all their endowed time for leisure.

Assuming that the household is a price taker in all markets, then the optimality conditions for the maximization of u(c; Z) subject to constraints (2.1)-(2.4) imply the following equations.

$$p_f f_x = [p_l\ p_v]^T, \tag{2.5.1}$$

$$u_c = \lambda[p_f\ p_m\ p_l]^T, \tag{2.5.2}$$

$$-p_f c_f - p_m c_m - p_l c_l = -M, \tag{2.5.3}$$

where $f_x = \partial f/\partial \mathbf{x}$, $u_c = \partial u/\partial c$, and $\lambda \geq 0$ denotes the Lagrange multiplier associated with the budget constraint (2.2). Note that column vectors are used for quantity variables while row vectors for price vectors, and that $\mathbf{v}^T$ denotes the transpose of a vector **v**. The equations in (2.5.1) and (2.5.2) imply that both the demand wage $p_f f_1(\cdot)$ and the supply wage $p_f u_3(\cdot)/u_1(\cdot)$ of this household should be equated to the market wage p_l:

$$p_f f_1(\cdot) = p_l = p_f u_3(\cdot)/u_1(\cdot), \tag{2.6}$$

where f_i and u_i denote the first derivatives of the functions f(·) and u(·) with respect to their *i*th argument.

However, Arayama (1986) and Kang and Maruyama (1992) 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, 1984) of off-farm employers among others.[5] 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'

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[5] Other studies give alternative explanations for the wage differential between on- and off-farm work. Shigeno (1989) 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 (1997) 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.

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,

$$L = T - c_l - x_l \leq \overline{L} = \text{constant.}^6 \tag{2.7}$$

The available employment $\overline{L}$ 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 (1984) or its closely related version by Bulow and Summers (1986) 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 (2.7) in addition to the budget constraint. The optimality conditions associated with this new problem imply the following augmented set of relations:

$$p_l^* \equiv p_l - \mu/\lambda \leq p_l, \tag{2.8}$$

$$p_f f_x = [p_l^* \; p_v]^T, \tag{2.9.1}$$

$$u_c = \lambda[p_f \; p_m \; p_l^*]^T, \tag{2.9.2}$$

$$-p_f c_f - p_m c_m - p_l^* c_l = -Y, \tag{2.9.3}$$

$$T - c_l - x_l - \overline{L} = 0, \tag{2.9.4}$$

where μ denotes the Lagrange multiplier associated with the constraint (2.9.4), which is a rearrangement of (2.7). Expressions Y and π^* stand for the full income and the residual profit imputable to the farm production activity, respectively, evaluated at the wage p_l^*:

$$Y \equiv p_l^* T + (p_l - p_l^*)\overline{L} + p_f x_f - p_l^* x_l - p_v x_v + I.$$

The equations in (2.9.1) and (2.9.2) imply that

$$p_f f_1(\cdot) = p_l^* = p_f u_3(\cdot)/u_1(\cdot). \tag{2.10}$$

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[6] The constrained off-farm wage employment may be plausible for Japanese rice farmers in case on- and off-farm labor are homogeneous as assumed in this chapter. The discussion in Chapter 4, however, will show that this type of homogeneity is rather restrictive.

The supply or reservation wage, $p_f u_3/u_1$, falls short of the market wage, p_l, due to effective constraint on off-farm employment and the household still seeks additional employment at the wage lower than the market wage. The term μ/λ represents the amount of discount it is prepared to allow. Since no additional off-farm employment is available, the household is obliged to put the remainder of its endowed time into its own production activity. Hence, the marginal revenue product of farm labor or the demand wage of this household, $p_f f_1$, in turn falls short of the market wage by the amount μ/λ.

Thus, in the case the off-farm employment constraint binds, it is not the market wage p_l but the discounted wage p_l^* that is relevant in determining the household's organization of production and its choice of consumption. Hence the wage p_l^* may be appropriately referred to as the equilibrium internal wage, which equilibrates the demand for labor, $x_l + L$, with its supply, $T - c_l$, within the household. The relations in (2.6) and (2.10) 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 equations in (2.9.1) that are directly associated with the determination of production organization share the endogenous internal wage p_l^* with the equations in (2.9.2) and (2.9.3) that are directly associated with the determination of consumption choice. Hence, the system of the equations in (2.9.1)-(2.9.4) 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 in 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.

2.3 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 (2.9.1)-(2.9.4). For the purpose of estimation to be carried out in the following section, the production and utility functions of the following types are specified.

$$\ln x_f = \ln\alpha + \Sigma_{i\in A}\,\beta_i \ln x_i + \beta_\psi \ln\psi + \beta_{tt}TT, \quad A \equiv \{l, v, k, t\}, \tag{2.11}$$

$$u = b_f \ln(c_f - a_f) + b_m \ln(c_m - a_m) + b_l \ln(c_l - a_l), \quad b_f + b_m + b_l = 1, \tag{2.12}$$

where x_k, x_t, ψ, 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 interpreted as the technological level in this study, respectively. See the subsequent section on data used for details of the set-aside program.

Equation (2.9.4) 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 (2.9.1)-(2.9.3) and those for the separable model in (2.5.1)-(2.5.3) 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 (2.11) into the optimality conditions in (2.9.1) provides the pseudo supply function of farm commodity

$$x_f = A_X \{ p_f^{(\beta_l+\beta_v)} p_l^{*(-\beta_l)} p_v^{(-\beta_v)} x_k^{\beta_k} x_t^{\beta_t} \psi^{\beta_\psi} \exp(\beta_{tt}TT) \}^{1/(1-\beta_l-\beta_v)}, \tag{2.13}$$

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.

$$\partial \ln x_f / \partial \ln s = (\partial \ln x_f / \partial \ln s)_{dp_l^*=0} + (\partial \ln x_f / \partial \ln p_l^*)(\partial \ln p_l^* / \partial \ln s), \tag{2.14}$$

This decomposition of the elasticities in terms of the internal wage p_l^* follows the method proposed by Sonoda and Maruyama (1998). 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 p_l^* caused by those in the same exogenous variable. The direct effects and the elasticity of x_f with respect to p_l^* are easily evaluated by use of (2.13). In evaluating the elasticities of commodity supply one must evaluate the elasticities $\partial \ln p_l^* / \partial \ln s$ 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 (2.9.1)-(2.9.4):

$$\begin{bmatrix} p_f f_{11} & p_f f_{12} & 0 & 0 & 0 & 0 & -1 \\ p_f f_{21} & p_f f_{22} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & u_{11} & u_{12} & u_{13} & -p_f & 0 \\ 0 & 0 & u_{21} & u_{22} & u_{23} & -p_m & 0 \\ 0 & 0 & u_{31} & u_{32} & u_{33} & -p_l^* & -\lambda \\ 0 & 0 & -p_f & -p_m & -p_l^* & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} dx_l \\ dx_v \\ dc_f \\ dc_m \\ dc_l \\ d\lambda \\ dp_l^* \end{bmatrix}$$

$$= \begin{bmatrix} -f_1 & 0 & -p_f f_{13} & -p_f f_{14} & -p_f f_{15} & 0 & 0 & 0 \\ -f_2 & 1 & -p_f f_{23} & -p_f f_{24} & -p_f f_{25} & 0 & 0 & 0 \\ \lambda & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \lambda & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ y_1 & x_v & -p_f f_3 & -p_f f_4 & -p_f f_5 & c_m & -1 & y_2 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} dp_f \\ dp_v \\ dx_k \\ dx_t \\ d\psi \\ dp_m \\ dI \\ dL \end{bmatrix}, \quad (2.15)$$

where $y_1 = c_f - x_f$, $y_2 = p_l^* - p_l$, and f_{ij} and u_{ij} denote the second derivatives of the functions $f(\cdot)$ and $u(\cdot)$.[7]

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_f of farm commodity rises. Figure 2.1 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

[7] To evaluate responses of endogenous variables to changes in ψ and η (η = per area subsidy on set-aside areas), unearned incomes I are divided into the subsidy IS on set-aside areas and others IO, while the total area planted x_t is divided into rice paddy TP and others TO which are not subject to the set-aside program. Since IS = $\eta\psi$TP, the case dIO = dTP = 0 implies dI = ($\psi d\eta + \eta d\psi$)TP.

labor; i.e., the left hand and right hand sides respectively of (2.10) which in turn states the equilibrium of this market, and the endowment in (2.9.4) of time of this household. Since the relevant wage in this market is the internal wage p_l^*, it is measured by the vertical axis in this figure. Expressions $L_{D,i}$ 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. Expressions $p_{l,i}^*$, $x_{l,i}$, L_i, and $c_{l,i}$ 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, $x_{l,i}$, is the sum of $x_{l,i}^{(1)}$ and $x_{l,i}^{(2)}$ in the figure. Since off-farm employment is constrained, the demand wage functions contain a horizontal segment of the length equal to $\overline{L}$. *From (2.15) the demand and supply functions in the present specifications turn out to be downward and upward sloping, respectively,*

$$\partial L_D / \partial p_l^* = (1-\beta_v)x_l / \{(1-\beta_l-\beta_v)p_l^*\} < 0,$$

$$\partial L_S / \partial p_l^* = (1-b_l)(c_l - a_l)/p_l^* > 0, \tag{2.16}$$

where $L_D \equiv x_l + L$ and $L_S \equiv T - c_l$. In the case where the price p_f of farm commodity rises, the household expands its demand x_l for farm labor in order to increase its supply of farm commodity as long as the internal wage remains constant at $p_{l,1}^*$. 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 p_l^* remains constant at $p_{l,1}^*$,

$$(\partial L_D / \partial p_f)_{dp_l^*=0} = x_l / \{(1-\beta_l-\beta_v)p_f\} > 0,$$

$$(\partial L_S / \partial p_f)_{dp_l^*=0} = -b_l(x_f - a_f)/p_l^* < 0 \quad \text{for } x_f > c_f.$$

The demand function shifts to the right, while the supply function to the left. Consequently, the internal wage rises from $p_{l,1}^*$ to $p_{l,2}^*$ in Figure 2.1 according to

$$\frac{\partial p_l^*}{\partial p_f} = \frac{b_l(1-\beta_l-\beta_v)(x_f - a_f) + \beta_l x_f}{(1-b_l)(1-\beta_l-\beta_v)(c_l - a_l) + (1-\beta_v)x_l} > 0 \quad \text{for } x_f > c_f. \tag{2.17}$$

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, 1991) 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:

$$\partial p_l^* / \partial s = -\{(\partial L_D / \partial s)_{dp_l^*=0} - (\partial L_S / \partial s)_{dp_l^*=0}\} / \{(\partial L_D / \partial p_l^*) - (\partial L_S / \partial p_l^*)\}.$$

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 p_l^* on the response of commodity supply x_f is represented by the internal wage effect in (2.14). We continue to examine the case of a rise in the price p_f of farm commodity to study this effect in more detail. In the case where the production function is specified in the form presented in (2.11), the own price elasticity of the commodity supply is evaluated as

$$\frac{\partial \ln x_f}{\partial \ln p_f} = \frac{\beta_l + \beta_v}{1 - \beta_l - \beta_v} + \frac{-\beta_l}{1 - \beta_l - \beta_v} \frac{\partial \ln p_l^*}{\partial \ln p_f}, \qquad (2.18)$$

where the elasticity $\partial \ln p_l^* / \partial \ln p_f$ corresponds to the derivative $\partial p_l^* / \partial p_f$ in (2.17). The first term on the right hand side represents the direct effect of a change in p_f, while the second its internal wage effect. The first term has a positive effect on the commodity supply because $\beta_l, \beta_v > 0$, and $1 - \beta_l - \beta_v > 0$ due to the positivity of marginal products and the concavity of the production function in (2.11). On the other hand, the second term has a negative sign because the positive elasticity $\partial \ln p_l^* / \partial \ln p_f$ is multiplied by its negative coefficient. Hence the sign of the combined effects depends on the relative importance of these two effects.

Figure 2.2 illustrates the supply response of farm commodity to a rise in its own price. $x_f(p_{l,i}^*)$ (i = 1, 2) represents the pseudo supply function of farm commodity with the internal wage evaluated at $p_{l,i}^*$. $p_{f,i}$ and $x_{f,i}$, 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 2.1. In the case where the price p_f rises from $p_{f,1}$ to $p_{f,2}$, the household expands its supply of farm commodity from $x_{f,1}$ to $x_{f,1}'$ as long as the internal wage remains constant at $p_{l,1}^*$. However, the internal wage does not remain constant but rises from $p_{l,1}^*$ to $p_{l,2}^*$ as shown both in (2.17) and in Figure 2.1, which in turn causes the demand for farm labor to be reduced. Therefore, the household will reduce its supply of farm commodity from x_{f1}' to x_{f2}, reflecting the internal wage effect in (2.18). In the case where the internal wage effect exceeds the direct effect of a rise in the price p_f as shown in Figure 2.2, the observed supply function of farm commodity will have a downward slope.

2.4 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.[8] 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_f of rice is estimated by dividing the production revenue from rice (yen) by its output x_f (kg). The market wage p_l for off-farm work is estimated by dividing the sum of wages, salaries, and other compensations by the corresponding off-farm work hours L. The price index p_v of current inputs (seeds and seedlings; fertilizers; feed; 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

[8] 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.

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, x_v, is estimated by dividing the sum of input expenditures by the corresponding price, p_v. The amount of real capital stock, x_k, is estimated similarly. The amount of rice consumed, c_f, is estimated by dividing the production revenue in excess of cash revenue from rice by the corresponding price, p_f. The numbers of on-farm workers, N_a, and off-farm workers, N_o, are adapted from FHET to estimate the endowed time of households at $T = 16 \times 365 \times (N_a + N_o)$. Leisure hours, c_l, are estimated by endowed time, T, in excess of the sum $x_l + L$ of on- and off-farm work hours. The rate of set-aside, ψ, 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.

Table 2.1 presents the means and standard deviations of main variables used in this study. The mean on- and off-farm work hours are estimated to be 1484 and 3384 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 (1986) and Kang and Maruyama (1992). 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.

2.5 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.

$$\ln x_f = \ln \alpha + \sum_{i \in A} \beta_i \ln x_i + \beta_\psi \ln \psi + \beta_{tt} TT + \sum_{j=1}^{7} \gamma_j RD_j + \sum_{k=2}^{7} \delta_k SD_k + u, \qquad (2.19)$$

where RD_j ($j = 1...7$) and SD_k ($k = 2...7$) denote regional and scale dummies and u an error term, respectively.

Both Jacoby (1993) and Skoufias (1994) 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 $p_v x_v / p_f x_f$ of the expenditure for current inputs to the production revenue should be equal to β_v:

$$p_v x_v / p_f x_f = \beta_v + v, \qquad (2.20)$$

where v denotes an error term. The error terms 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 β_v to differ among different regions and different scales of paddy field:

$$\beta_v = \varepsilon_0 + \sum_{j=1}^{7} \varepsilon_j RD_j + \sum_{k=2}^{7} \phi_k SD_k \,. \tag{2.21}$$

For the data used in this study, the number of households N_{jk} included in each class differs greatly among different region j as well as among different scale k. Thus, equations (2.19) and (2.20) with the relation in (2.21) 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 $\ln x_l$ and $\ln x_v$ are treated as endogenous. To obtain more precise estimates of β_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 (x_k, x_t, ψ, and TT), and other costs in production, OC. Furthermore, the two sets of parameters (ε_j, ϕ_k) (j = 0...7; k = 2...7) which appear simultaneously in (2.19) and (2.20) were tested for equality by use of an LM test proposed by Newey and West.

The internal wage is estimated by use of the relation $p_l^* = \hat{\beta}_l p_f \hat{x}_f / x_l$ ($\hat{x}_f$ being fitted value of x_f) and is used to estimate parameters of the utility function. The specification in (2.12) of the household utility function and the optimality conditions in (2.9.2) and (2.9.3) yield a system of three expenditure equations similar to the linear expenditure system with the internal wage p_l^* and the full income Y 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,

$$p_f c_f = a_f p_f + b_f (Y - a_f p_f - a_m p_m - a_l p_l^*) + \sum_{j=1}^{7} c_j RD_j + \sum_{k=1}^{7} d_k SD_k + \tau_f TT + u_f, \tag{2.22}$$

$$p_m c_m = a_m p_m + b_m (Y - a_f p_f - a_m p_m - a_l p_l^*) + \sum_{j=1}^{7} g_j RD_j + \sum_{k=1}^{7} h_k SD_k + \tau_m TT + u_m, \tag{2.23}$$

where u_f and u_m are error terms. Furthermore, the number N_f of household members as well as the share FS of farm workers N_a in all workers $N_a + N_o$ are used as shift factors of the utility function to allow for different composition of members among different households:

$$a_i = a_{i,0} + a_{i,1}N_f + a_{i,2}FS \quad (i = f, m, l). \tag{2.24}$$

Since p_l^* and Y are endogenous, equations (2.22) and (2.23) with the relations (2.24) 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_f, p_m, p_v, TAX, N_f, and FS in addition to the instruments already used to estimate parameters of the production function, where TAX denotes the amount taxed available from FHET.

Estimated coefficients of equations (2.19) and (2.20) with the relation (2.21) incorporated are shown in Table 2.2, where estimates of the coefficients γ_j and δ_k are not shown.[9] The LM test statistic is compared with the critical value of the χ^2 distribution with 11 degrees of freedom to show that the equality of the two sets of parameters (ε_j, ϕ_k) in (2.19) and (2.20) is not rejected at any reasonable level of significance. The coefficients β_l, β_k, and β_t of factor inputs are positive and all of them are significant at the 10% level. The coefficient β_ψ of the rate ψ of set-aside is significantly negative, so that a rise in ψ reduces the output of rice with other things being equal. Furthermore, the relation in (2.21) and the estimates of parameters (ε_j, ϕ_k) give estimates of β_v, whose average and standard deviation prove to be 0.1644 and 0.0226, respectively.

The elasticity β_l of output with respect to farm labor plays the most important role in determining the level of the internal wage p_l^*. Among other authors who have estimated this elasticity for Japanese rice farmers, Shintani (1983) estimates it at 0.26 for the periods 1969-71 and 1977-79 by use of a Cobb-Douglas production function, while Kusakari (1985) 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 β_l seems to be reasonable.

---

[9] The coefficients of determination in the first stage regressions of $\ln x_l$ and $\ln x_v$ on the instruments are 0.92 and 0.97, respectively.

Table 2.3 presents estimated coefficients of equations (2.22) and (2.23) with the relations (2.24) incorporated.[10] Most of the coefficients are statistically significant and concavity of the utility function is satisfied at the mean values of the relevant variables. The estimated coefficients of shift factors of the utility function indicate that an increase in the number of household members, N_f, raises the household's subsistence level for all commodities, while an increase in the share of farm workers, FS, has an effect of lowering the household's subsistence level.

2.6 Testing the Bindingness of Off-farm Employment Constraint

From the estimated coefficients in Table 2.2, 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 2.4, 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 (1994), the equation $\ln p_l^* = a + b\ln p_l$ 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 (1994) 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:

$\ln p_l^* = 9.711 - 0.505\ln p_l$, Ftest = 1620.5,

where Ftest 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.

---

[10] The coefficients of determination in the first stage regressions of p_l^* and Y on the instruments are 0.96 and 0.94, respectively.

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 $D_i = p_{I,i} - p^*_{I,i}$ (i = 1…n, n = 283) by means of the Jarque-Bera test (see, e.g., Davidson and Mackinnon, 1993). The normalized difference between the two wages is defined as $ND_i = (D_i - \overline{D})/s_D$, where $\overline{D}$ 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: α = 0 against its alternative H_1: $\alpha > 0$. We can construct a test statistic $t = n^{1/2}(\overline{D} - \alpha)/s_D$ 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 p^*_I proves to be significantly lower than that of p_I.

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.

2.7 Estimated Elasticities of Rice Supply and the Internal Wage

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 2.5. The values for the separable model are estimated from those values for the non-separable model by setting $dp_l^* = 0$ 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 (2.16), 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_f and $\overline{L}$ 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_f and $\overline{L}$, $x_f/(1-\beta_l-\beta_v)L_D$ and $\overline{L}/L_D$ 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, $-b_l p_f(x_f - a_f)/p_l^* L_S$ and $b_l(p_l^* - p_l)\overline{L}/p_l^* L_S$ 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_f 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 2.2. 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 (2.16) implies that $\partial \ln L_S / \partial \ln p_l^* = (1 - b_l)(c_l - a_l)/(x_l + L)$, which is the "marginal propensity to work" $(1 - b_l)$ times the ratio of "discretionary time" $(c_l - a_l)$ to the sum $(x_l + L)$ 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 ψ 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, η, 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 $\overline{L}$ 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.

2.8 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 chapter 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.

Table 2.1. Description, Mean, and Standard Deviation of Main Variables

Variable	Description	Mean	Std. Dev.
x_f	Amount of rice produced (kg)	9320.5	6594.9
x_{lm}	On-farm work hours for males	779.7	412.1
x_{lf}	On-farm work hours for females	704.6	282.5
x_l	On-farm work hours	1484.3	672.6
x_v	Amount of other variable inputs	4396.2	2762.8
x_k	Amount of real capital stock	30340.2	14066.6
x_t	Total area planted (a)	214.2	138.7
ψ	Intensity rate of the set-aside program	0.161	0.049
c_f	Amount of rice consumed (kg)	567.0	173.4
c_m	Amount of purchased market commodities	52971.2	7764.2
c_{lm}	Leisure hours for male on-farm workers	1899.8	1385.2
c_{lf}	Leisure hours for female on-farm workers	1696.9	980.3
c_{lo}	Leisure hours for off-farm workers	7255.4	1604.4
c_l	Leisure hours for total members	10852.0	1663.7
L	Off-farm work hours	3384.1	734.9
N_{male}	Number of male family members	2.380	0.402
N_{female}	Number of female family members	2.484	0.378
N_f	Number of family members	4.864	0.708
N_{lm}	Number of male on-farm workers	0.459	0.304
N_{lf}	Number of female on-farm workers	0.411	0.212
N_a	Number of on-farm workers	0.870	0.506
N_o	Number of off-farm workers	1.822	0.388
p_f	Price of rice (yen/kg)	324.0	16.00
p_m	Price index for purchased market commodities	97.77	4.468
p_{lo} (p_l)	Off-farm wage (yen/hour)	1301.8	284.4
p_v	Price index for other variable inputs	105.8	5.507

Table 2.2. Estimated Coefficients of Equations (2.19) and (2.20) with the Relation (2.21) Incorporated

β_l	0.2502	(3.513)
β_k	0.0549	(1.689)
β_t	0.2840	(3.056)
β_ψ	−0.0781	(3.486)
β_{tt}	0.0099	(3.556)
ε_0	0.1772	(45.463)
ε_1	−0.0339	(10.306)
ε_2	−0.0314	(9.559)
ε_3	−0.0233	(6.337)
ε_4	−0.0088	(2.045)
ε_5	−0.0201	(5.104)
ε_7	−0.0234	(2.536)
ϕ_2	0.0286	(9.161)
ϕ_3	0.0151	(4.299)
ϕ_6	−0.0109	(1.557)
ϕ_7	−0.0100	(2.228)
R_f^2	0.9997	
R_v^2	0.9730	
J-test	10.140	[0.428]
LM	0.122	{ 1.000}

Note: Some of the coefficients ε_i and ϕ_j are set equal to nil in this final estimation. R_f^2 and R_v^2 denote the coefficients of determination for equations (2.19) and (2.20) respectively and J-test a χ^2 statistic associated with the overidentifying restrictions test. LM denotes an LM statistic to test the equality of the two sets of parameters (ε_j, ϕ_k) in (2.19) and (2.20). 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 2.3. Estimated Coefficients of Equations (2.22) and (2.23) with the Relations (2.24) Incorporated

$a_{f,0}$	-1460.2	(1.459)
$a_{f,1}$	561.8	(2.354)
$a_{f,2}$	-2501.5	(1.925)
$a_{m,0}$	-57989.3	(1.935)
$a_{m,1}$	22810.1	(4.780)
$a_{m,2}$	-113912.0	(5.582)
$a_{l,0}$	-8370.9	(1.681)
$a_{l,1}$	4678.2	(3.972)
$a_{l,2}$	-15307.6	(2.836)
b_f	0.0431	(2.231)
b_m	0.5040	(9.076)
b_l	0.4529	(7.573)
τ_f	-7888.8	(3.647)
τ_m	43096.9	(3.755)
R_f^2	0.8619	
R_m^2	0.9915	
J-test	21.585	[0.119]

Note: R_f^2 and R_m^2 denote the coefficients of determination for equations (2.22) and (2.23) respectively and J-test a χ^2 statistic associated with the overidentifying restrictions test. The value of b_l is estimated by use of the relation $b_f + b_m + b_l = 1$. Absolute values of t-statistics are shown in parentheses ( ) and the upper tail area for $\chi^2(15)$ in brackets [ ].

Table 2.4. 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)
Total Sample	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 2.5. Estimated Elasticities of Rice Supply and the Internal Wage

	Non-Separable Model	Separable Model
$\partial \ln x_f / \partial \ln p_f$	−0.121	0.708
$\partial \ln x_f / \partial \ln p_v$	−0.149	−0.281
$\partial \ln x_f / \partial \ln x_k$	0.047	0.094
$\partial \ln x_f / \partial \ln x_t$	0.243	0.485
$\partial \ln x_f / \partial \ln \psi$	−0.083	−0.133
$\partial \ln x_f / \partial \ln p_m$	0.251	0.000
$\partial \ln x_f / \partial \ln \eta$	−0.016	0.000
$\partial \ln x_f / \partial \ln L$	−0.920	0.000
$\partial \ln p_l^* / \partial \ln p_f$	1.941	0.000
$\partial \ln p_l^* / \partial \ln p_v$	−0.308	0.000
$\partial \ln p_l^* / \partial \ln x_k$	0.110	0.000
$\partial \ln p_l^* / \partial \ln x_t$	0.566	0.000
$\partial \ln p_l^* / \partial \ln \psi$	−0.117	0.000
$\partial \ln p_l^* / \partial \ln p_m$	−0.586	0.000
$\partial \ln p_l^* / \partial \ln \eta$	0.038	0.000
$\partial \ln p_l^* / \partial \ln L$	2.153	0.000

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

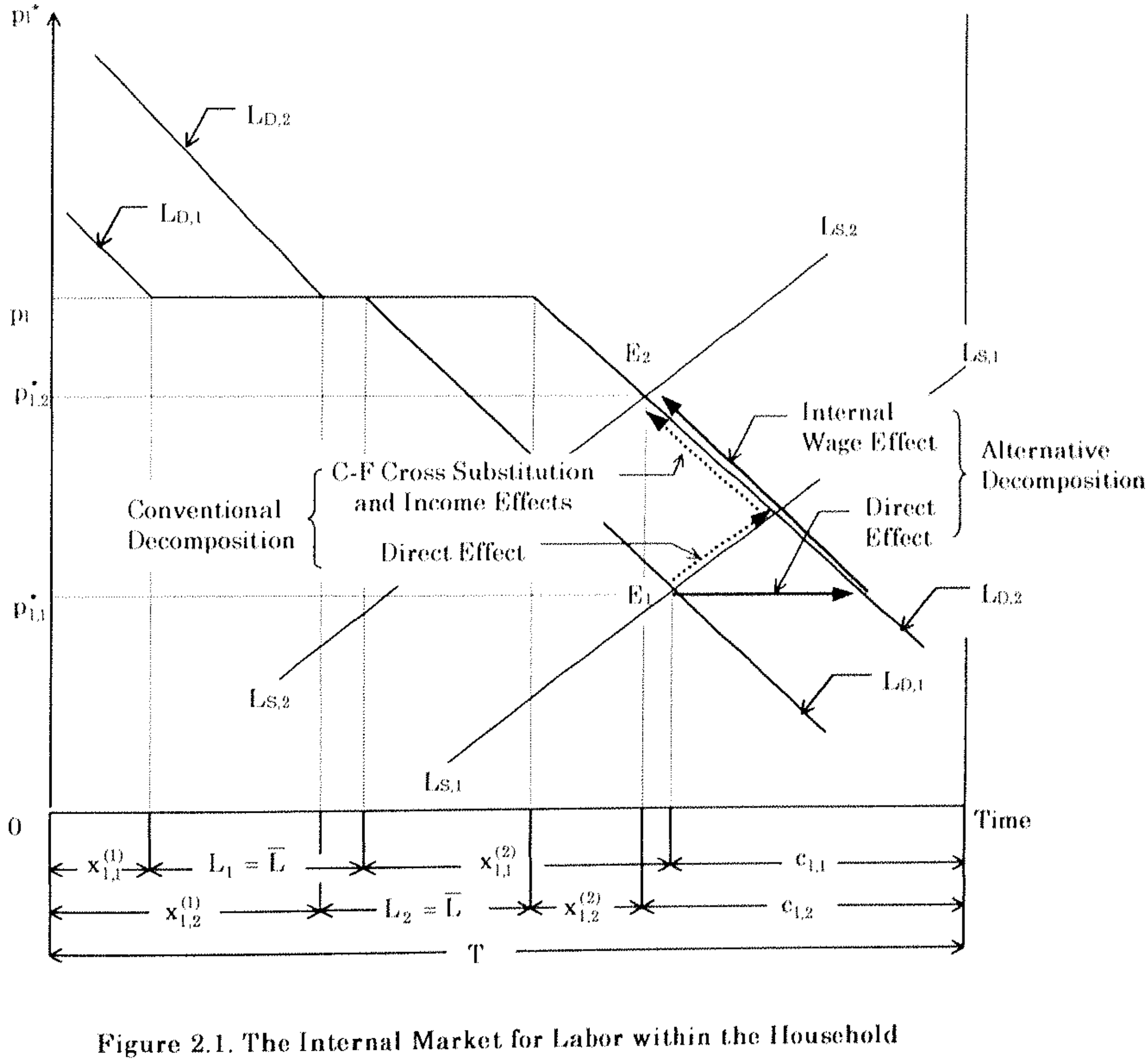

Figure 2.1. The Internal Market for Labor within the Household

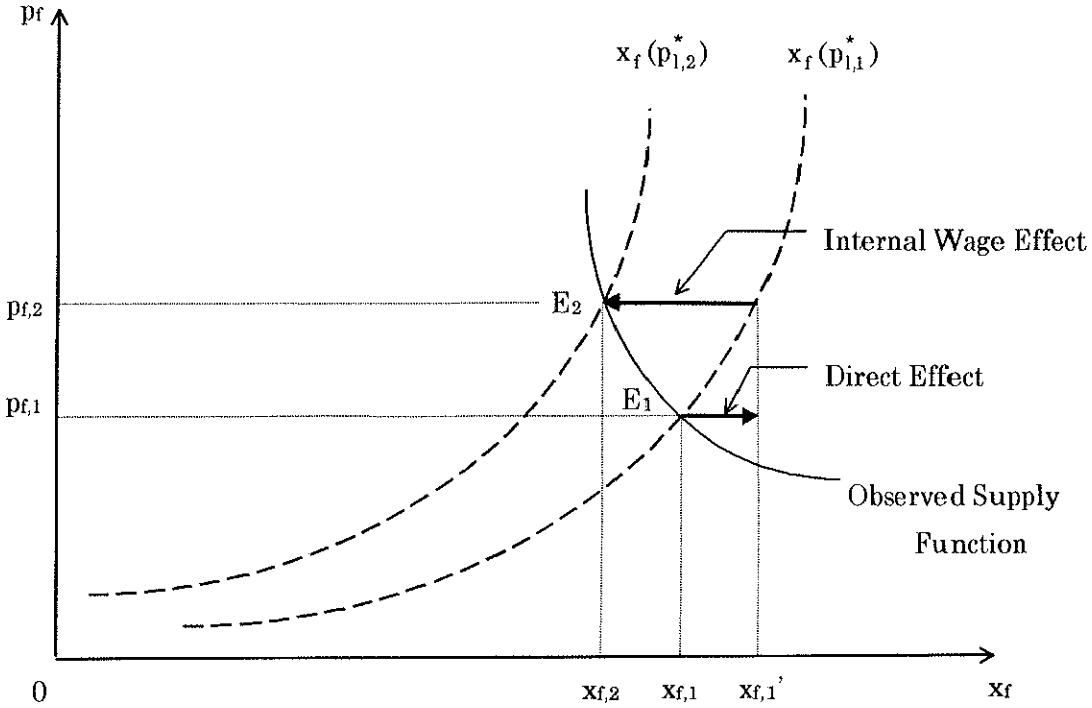

Figure 2.2. Response of the Supply of Farm Commodity to a Change in Its Price

Appendix

An Alternative Decomposition of Comparative Statics in the Agricultural Household Model with Constrained Off-Farm Wage Employment

In Chapter 2, the response of output supply was examined for specific types of production and utility functions with special reference to the "internal wage". This Appendix presents an alternative decomposition analysis in this line for a general class of production and utility functions and compares it with the conventional decomposition analysis made by Sasaki and Maruyama (1966).

A.1 Difficulties Facing the Conventional Analysis of Comparative Statics

Two types of approaches have been taken for the detailed comparative statics analysis of the nonseparable agricultural household model under absent or constrained off-farm wage employment. One directly works with the optimality conditions associated with the household's utility maximization, which may be referred to as a primal approach (e.g., Sasaki and Maruyama, 1966; Maruyama, 1975). The other first defines the internal wage (or the virtual price of labor) implicitly in terms of the expenditure and profit functions, then makes the comparative statics analysis of endogenous variables by use of "pseudo" demand and supply functions which include in their arguments the endogenous internal wage in place of the exogenous market wage. The second approach may be referred to as a dual approach (e.g., Strauss, 1986; Besley, 1988).

The primal approach tries to decompose all terms of the comparative statics analysis into the income and substitution effects. This gives rise to the "commodity-factor cross substitution effect" (Sasaki and Maruyama, 1966) and the income effect in the analysis of production organization while the commodity-factor cross substitution effect and the income effect in the analysis of consumption choice. These cross effects are not readily amenable to the standard theory of microeconomic analysis in which the production organization is analyzed separately from the consumption choice, which seems to have reduced the tractability of the nonseparable model in empirical applications.[1]

On the other hand, the dual approach decomposes responses of quantity variables into the direct effect of changes in exogenous variables with the internal wage fixed and the indirect effect of changes in the internal wage caused by those in the same exogenous variables. Thus, all terms in the comparative statics analysis turn out to be amenable to the standard theory, because changes in the internal wage are treated as changes in a factor price in the analysis of production organization while as those in a commodity price in the analysis of consumption choice. Nonetheless, few studies have taken the dual approach to estimate structural parameters of the nonseparable agricultural household model in empirical studies. This may be partly because the internal wage is not observable but is to be estimated usually by use of production functions as in Jacoby (1993) and Skoufias (1994). However, if a flexible production function is specified for this purpose, it is difficult to derive the properties of the corresponding profit functions required for its comparative statics analysis.

One way to circumvent these difficulties may be to follow the primal approach but to decompose responses of quantity variables in a way similar to the dual approach. The following analysis will show that this can be done by paying special attention to the internal wage equilibrating the demand for labor with its supply within the household.

A.2 An Alternative Decomposition of the Response of Quantity Variables

Responses of the household to changes in the market prices are examined here. Differentiating the equations in (2.9.1)-(2.9.4) of Chapter 2 with respect to the market prices $\mathbf{p} = [p_f\ p_v\ p_m\ p_l]$, the result is shown compactly in a matrix expression:

---

[1] In separable agricultural household models, by contrast, the analysis of production organization is independent of that of consumption choice, and furthermore the latter is affected by the former only through changes in full income, i.e., "profit effects" (Strauss, 1986). Hence, the separable models are quite amenable to the standard theory of microeconomic analysis and have been frequently used for empirical studies (e.g., Lau, Lin, and Yotopoulos, 1978).

$$
\begin{bmatrix} p_f f_{xx} & 0 & 0 & (e_2)^T \\ 0 & u_{cc} & -(p^*_{-v})^T & \lambda(e_3)^T \\ 0 & -p^*_{-v} & 0 & 0 \\ e_2 & e_3 & 0 & 0 \end{bmatrix} \begin{bmatrix} dx \\ dc \\ d\lambda \\ dp^*_l \end{bmatrix} = \begin{bmatrix} [-f_1 dp_f \ \ (dp_v - f_2 dp_f)]^T \\ \lambda[dp_f \ dp_m \ 0]^T \\ -d\eta \\ 0 \end{bmatrix}, \qquad (A.1)
$$

where $f_{xx} = \partial^2 f/\partial x^2$, $u_{cc} = \partial^2 u/\partial c^2$, $e_2 = [-1\ 0]$, $e_3 = [0\ 0\ -1]$, and $-d\eta = (c_f - x_f)dp_f + x_v dp_v + c_m dp_m - \bar{L} dp_l$. Expression p^*_{-v} denotes the row vector of the prices p_f, p_m, and p^*_l. The expression (A.1) is rewritten as

$$
\begin{bmatrix} p_f f_{xx} & 0 & 0 \\ 0 & u_{cc} & -(p^*_{-v})^T \\ 0 & -p^*_{-v} & 0 \end{bmatrix} \begin{bmatrix} dx \\ dc \\ d\lambda \end{bmatrix} + \begin{bmatrix} (e_2)^T \\ \lambda(e_3)^T \\ 0 \end{bmatrix} dp^*_l = \begin{bmatrix} [-f_1 dp_f \ \ (dp_v - f_2 dp_f)]^T \\ \lambda[dp_f \ dp_m \ 0]^T \\ -d\eta \end{bmatrix}, \qquad (A.2.1)
$$

$$
-dx_l - dc_l = 0. \qquad (A.2.2)
$$

Equation (A.2.2) can be suppressed without loss of analytical rigor when the household is in equilibrium, although it must be taken into consideration in case responses of the internal wage itself are to be examined. Then, (A.2.1) can be written in a separated form:

$$
B dx = -(e_2)^T dp^*_l + [-f_1 dp_f \ \ (dp_v - f_2 dp_f)]^T, \qquad (A.3.1)
$$

$$
C \begin{bmatrix} dc \\ d\lambda \end{bmatrix} = -\begin{bmatrix} \lambda(e_3)^T \\ 0 \end{bmatrix} dp^*_l + \begin{bmatrix} \lambda[dp_f \ dp_m \ 0]^T \\ -d\eta \end{bmatrix}, \qquad (A.3.2)
$$

where

$$
B = p_f f_{xx}, \quad C = \begin{bmatrix} u_{cc} & -(p^*_{-v})^T \\ -p^*_{-v} & 0 \end{bmatrix}.
$$

To obtain the response of quantity variables in their explicit form, define $B^{-1} = (b^{ij})$ (i, j = 1, 2) and $C^{-1} = (c^{ij})$ (i, j = 1, 2, 3, 4). The elements b^{ij} and c^{ij} are used to define the vectors $b^i = [b^{1i}\ b^{2i}]^T$ (i = 1, 2) and $c^i = [c^{1i}\ c^{2i}\ c^{3i}]^T$ (i = 1, 2, 3). Then, it can be shown from (A.3.1) and (A.3.2) that the response of quantity variables to changes in the market price p can be written as

$$
\partial x/\partial p = [(-f_1 b^1 - f_2 b^2) \quad b^2 \quad 0 \quad 0] + (\partial p^*_l/\partial p) \otimes b^1, \qquad (A.4.1)
$$

$$
\partial c/\partial p = [\{\lambda c^1 + (c_f - x_f)c^4\} \quad x_v c^4 \quad (\lambda c^2 + c_m c^4) \quad -\bar{L} c^4] + (\partial p^*_l/\partial p) \otimes c^3, \qquad (A.4.2)
$$

where 0 in these equations is a 2×1 vector of zeros. The result of a similar analysis for the separable model can be obtained when the response of the internal wage, $\partial p^*_l/\partial p$, is set equal to 0 and the internal wage p^*_l is evaluated at the market wage p_l.

Equations (A.4.1) and (A.4.2) explicitly show that the response of quantity variables can be decomposed into two parts, one representing the direct effect of changes in the exogenous market prices and the other representing the indirect effect of changes in the internal wage p_l^* caused by those in the same exogenous market prices. The latter effect is not present in the separable competitive case, where p_l^* is identical to the market wage p_l and is not directly affected by changes in exogenous variables other than p_l itself. This indirect effect may be referred to as an "internal wage effect" by its construction, which is unique to the nonseparable case and plays an important role in coordinating changes in the production organization and those in the consumption choice. Responses of the internal wage p_l^* itself will be somewhat closely examined in the next subsection.

Now, these results of the alternative decomposition will be compared with the corresponding ones of the conventional decomposition (e.g., Sasaki and Maruyama, 1966) to characterize the former. Conventionally, the decomposition analysis has been directly applied to the equations in (A.1) without distinguishing the internal wage p_l^* from other endogenous variables, so that its role is submerged obscurely in the overall analysis of comparative statics. To see this more closely, let A denote the matrix of coefficients on the left hand side of (A.1) and let $A^{-1} = (a^{ij})$ (i, j = 1,...,7). Then, it can be shown that the response of quantity variables expressed in the conventional way is as follows:

$$\partial \mathbf{x}/\partial \mathbf{p} = [\{-f_1\mathbf{a}_x^1 - f_2\mathbf{a}_x^2 + \lambda\mathbf{a}_x^3 + (c_f - x_f)\mathbf{a}_x^6\} \quad (\mathbf{a}_x^2 + x_v\mathbf{a}_x^6) \quad (\lambda\mathbf{a}_x^4 + c_m\mathbf{a}_x^6) \quad -\overline{L}\mathbf{a}_x^6], \tag{A.5.1}$$

$$\partial \mathbf{c}/\partial \mathbf{p} = [\{-f_1\mathbf{a}_c^1 - f_2\mathbf{a}_c^2 + \lambda\mathbf{a}_c^3 + (c_f - x_f)\mathbf{a}_c^6\} \quad (\mathbf{a}_c^2 + x_v\mathbf{a}_c^6) \quad (\lambda\mathbf{a}_c^4 + c_m\mathbf{a}_c^6) \quad -\overline{L}\mathbf{a}_c^6], \tag{A.5.2}$$

where $\mathbf{a}_x^i = [a^{1i} \ a^{2i}]^T$ and $\mathbf{a}_c^i = [a^{3i} \ a^{4i} \ a^{5i}]^T$ (i = 1, 2, 3, 4, 6).

The comparison of the response of quantity variables in (A.4.1) and (A.4.2) with those in (A.5.1) and (A.5.2) is summarized in Table A.1. The table contains various effects which appear in the responses $\partial x/\partial \alpha$ and $\partial c/\partial \alpha$ decomposed by the two methods, where α denotes the market price p_f, p_v, p_m, or p_l. For example, the response $\partial x/\partial p_f$ is decomposed into the direct effect, $-f_1a_x^1 - f_2a_x^2$, the "commodity-factor substitution effect" (Sasaki and Maruyama, 1966), λa_x^3, and the income effect, $(c_f - x_f)a_x^6$, by the conventional method,[2] while it is decomposed into the direct effect, $-f_1b^1 - f_2b^2$, and the internal wage effect, $(\partial p_l^* / \partial p_f)b^1$ in the alternative one. The dotted lines in the table are drawn in case an effect (or effects) in one decomposition has its (or their) counterpart in the other.[3] Then, it is found from this table that the pairs of the commodity-factor cross substitution and the income effects in the conventional decomposition of $\partial x/\partial \alpha$ correspond to the internal wage effects in the alternative one wherever all these effects are relevant. It is also found that the similar pairs in the conventional decomposition of $\partial c/\partial \alpha$ correspond to the internal wage and the income effects in the alternative one wherever all these effects are relevant. Hence, it should be clear from this examination that the alternative decomposition can do without both the commodity-factor cross substitution and the income effects in the analysis of production organization and furthermore that it can do without the commodity-factor cross substitution effect in the analysis of consumption choice.[4]

A.3 Response of the Internal Wage

Now, we turn to the examination of responses of the internal wage itself. The equations in (A.4.1) and (A.4.2) show that the response of farm labor x_l and leisure consumption c_l can be written as

$$\partial Q / \partial \alpha = (\partial Q / \partial \alpha)_{dp_l^*=0} + (\partial Q / \partial p_l^*)(\partial p_l^* / \partial \alpha), \quad Q = x_l, c_l. \qquad \text{(A.6)}$$

Furthermore, from equation (A.2.2) which has been suppressed so far,

[2] The commodity-factor cross substitution effects describe the indirect substitution between farm labor (or leisure) and other commodities (or other factors) mediated through the substitution between leisure (or farm labor) and other commodities (or other factors).

[3] Since income effects appear both in the conventional and alternative decompositions of $\partial c/\partial \alpha$, one may wonder why the dotted lines for these effects are not drawn. It should be noticed, however, that the internal wage effect will have no counterpart for $\alpha = p_m$ and $\alpha = p_l$ if the lines are drawn.

[4] It should be noted that this does not imply that the sum of the commodity-factor cross substitution effect and the income effect is equal to the corresponding internal wage effect. This point will be examined in Figure 2.1.

$$(\partial x_l / \partial \alpha) + (\partial c_l / \partial \alpha) = 0. \tag{A.7}$$

Then, the response of the internal wage is obtained by substituting (A.6) into (A.7),

$$\partial p_l^* / \partial \alpha = -\{(\partial x_l / \partial \alpha)_{dp_l^*=0} + (\partial c_l / \partial \alpha)_{dp_l^*=0}\} / \{(\partial x_l / \partial p_l^*) + (\partial c_l / \partial p_l^*)\}. \tag{A.8}$$

The first and second terms in the numerator on the right hand side respectively represent the response of farm labor x_l and leisure consumption c_l to changes in the market price α with the internal wage p_l^* being fixed at its equilibrium level. Whereas the first and second terms in the denominator respectively represent their response to changes in the internal wage itself.

The explicit form of the terms in (A.8), $\partial x_l / \partial p_l^*$ and $\partial c_l / \partial p_l^*$, are obtained from (A.3.1) and (A.3.2) as

$$\partial x_l / \partial p_l^* = p_f f_{22} / |B| < 0,$$

$$\partial c_l / \partial p_l^* = \lambda C_{33} / |C| < 0,$$

where $f_{22} = \partial^2 f / \partial x_v^2$, and C_{33} denotes the cofactor associated with the element c_{33} in $|C|$ and thus has the sign opposite to $|C|$. Hence, the internal wage rises, falls, or is left invariant according as the sum of the response of farm labor and leisure consumption increases, decreases, or remains constant with the internal wage being fixed. For $\alpha = p_f$, it can be shown from (A.4.1) and (A.4.2) that [5]

$$(\partial x_l / \partial p_f)_{dp_l^*=0} = p_f (f_2 f_{12} - f_1 f_{22}) / |B|,$$

$$(\partial c_l / \partial p_f)_{dp_l^*=0} = \lambda c^{11} + (x_f - c_f)(\partial c_l / \partial Y),$$

where the term λc^{11} turns out to represent the commodity substitution effect from Table A.1. Hence, the response of the internal wage p_l^* to changes in the price p_f of farm commodity proves to be positive if $f_{12} > 0$, $x_f > c_f$, and leisure is normal and is a good substitute for farm commodity.

[5] It is easy to show from (A.3.1) and (A.3.2) that $b^{11} = p_f f_{22}$, $b^{12} = -p_f f_{12}$, and $c^{34} = -\partial c_l / \partial Y$.

A.4 An Intuitive Interpretation of the Alternative Decomposition

In Figure 2.1, the response of the demand for farm labor, x_l, is decomposed by the conventional and alternative methods, where c-f cross substitution effect in the figure refers to the commodity-factor cross substitution effect. In the conventional decomposition (arrows with dotted lines), the direct effect of a rise in the price p_f is represented by the rightward shift of the labor demand function along the labor supply function in period 1, $L_{S,1}$. Then, the commodity-factor cross substitution and income effects, reflecting the leftward shift of the labor supply function, reduce the demand for farm labor down to the level corresponding to the point E_2. Whereas in the alternative decomposition (arrows with solid lines), the direct effect of a rise in the price p_f is represented by the rightward shift of the labor demand function with the internal wage being fixed at $p^*_{l,1}$. This direct effect turns out to be similar to the corresponding effect in the separable competitive model, where the determination of labor demand is independent of that of labor supply. Since the demand for labor exceeds its supply at $p^*_{l,1}$, the internal wage rises to $p^*_{l,2}$ to restore the equilibrium between the demand for and the supply of labor within the household. The rise in the internal wage, in turn, has an additional internal wage effect of reducing the demand for farm labor down to the level corresponding to the point E_2.

Table A.1. Comparison of the Conventional and Alternative Decompositions

	Decomposition of $\partial x/\partial\alpha$		Decomposition of $\partial c/\partial\alpha$	
	Conventional	Alternative	Conventional	Alternative
$\alpha = p_f$	$-f_1 a_x^1 - f_2 a_x^2$ (direct) λa_x^3 (c-f cross sub.) $(c_f - x_f)a_x^6$ (income)	$-f_1 b^1 - f_2 b^2$ (direct) $(\partial w^*/\partial p_f)b^1$ (internal wage)	λa_c^3 (commod. sub.) $-f_1 a_c^1 - f_2 a_c^2$ (c-f cross sub.) $(c_f - x_f)a_c^6$ (income)	λc^1 (commod. sub.) $\lambda(\partial w^*/\partial p_f)c^3$ (internal wage) $(c_f - x_f)c^4$ (income)
$\alpha = p_v$	a_x^2 (factor sub.) $x_v a_x^6$ (income)	b^2 (factor sub.) $(\partial w^*/\partial p_v)b^1$ (internal wage)	a_c^2 (c-f cross sub.) $x_v a_c^6$ (income)	$\lambda(\partial w^*/\partial p_v)c^3$ (internal wage) $x_v c^4$ (income)
$\alpha = p_m$	λa_x^4 (c-f cross sub.) $c_m a_x^6$ (income)	$(\partial w^*/\partial p_m)b^1$ (internal wage)	λa_c^4 (commod. sub.) $c_m a_c^6$ (income)	λc^2 (commod. sub) $\lambda(\partial w^*/\partial p_m)c^3$ (internal wage) $c_m c^4$ (income)
$\alpha = w$	$-\bar{L}a_x^6$ (income)	$(\partial w^*/\partial w)b^1$ (internal wage)	$-\bar{L}a_c^6$ (income)	$\lambda(\partial w^*/\partial w)c^3$ (internal wage) $-\bar{L}c^4$ (income)

Note: The abbreviations "commod.", "sub.", and "c-f" refer to "commodity", "substitution", and "commodity-factor", respectively.