Labor supply, income, and welfare of the farm household ☆

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ARTICLE INFO

ABSTRACT

Considering family labor and hired labor as heterogeneous inputs, we present a theoretical framework in which the optimal decisions of a farm household on on-farm family and hired labor, off-farm labor supply, and leisure are determined uniquely and endogenously. Focusing on two alternative settings with and without off-farm employment constraints, we show that imperfect substitutability between family labor and hired labor is not critical to the separation of household production and consumption. The validity of the separation proposition is shown to depend crucially on whether or not the availability of off-farm job opportunities is limited. We further examine how changes in external economic conditions and government policies affect the time allocation decisions of the household, as well as the composition of household income (i.e., on-farm income and off-farm labor earnings).

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1. Introduction

Issues on the separation of production and consumption decisions in the farm household have long been of interest to economists.[3] The farm household is characterized by a dual role in producing marketable output and coordinating consumption of its members through the allocation of time between work (on-farm and/or off-farm) and leisure. Investigating the separation proposition is important because separation allows for independent estimation of production and consumption, on the one hand, and serves as a foundation for the separate supply and demand analyses in the neoclassical economics, on the other. In a seminal contribution, Benjamin (1992) raised an important issue concerning whether the validity of the separation hypothesis ceases to hold when "family and hired labor are not perfect substitutes in production" (p. 290). One question of interest is:

Would studies showing that family and hired labor are imperfect substitutes be sufficient to undermine the separation proposition?

In this paper, we show that imperfect substitutability between family and hired labor is not critical to the separation between household production and consumption. Interestingly, the validity of the separation proposition depends crucially on whether or not the availability of off-farm job opportunities is limited. To allow for imperfect substitutability, we incorporate a neoclassical-type production function into the traditional income-leisure framework and examine the labor supply and production decisions of a farm household in which family and hired labor are heterogeneous. The assumption of the heterogeneity of labor inputs is supported by several studies on agrarian production.[4] In particular, this assumption parallels Schultz's (1999, p. 7) observation that "family and hired labor may exhibit different productivity and may deserve to be treated as separate inputs."

In the analysis, we first present a model with flexible off-farm job opportunities to characterize the endogenous behavior of a farm household in which on-farm family and hired labor, off-farm labor supply, and leisure are uniquely determined. We further analyze the case with off-farm job constraints. Based on the alternative settings, we examine how changes in economic conditions and government policies affect the labor and production decisions of the household. Further, we discuss the effects of these external changes and government policies on total household income and its composition (i.e., on-

[3] See, e.g., Barnham and Squire (1979), Strauss (1984, 1986), Lopez (1986), Singh et al. (1986), Huffman (1991), Benjamin (1992), Schultz (1999), Woldehanna et al. (2000), Taylor and Adelman (2003), Benjamin and Kimhi (2006), Kwon et al. (2006), Hennessy and Rehman (2008), and Lien et al. (2010).

[4] See, e.g., Deolalikar and Vijverberg (1983, 1987), Eswaran and Kotwal (1986), Fafchamps and Quisumbing (1999), Frisvold (1994), Jacoby (1993), Schultz (1999), and Benjamin and Kimhi (2006).

farm income and off-farm labor earnings), as well as on household welfare (i.e., utility). Special emphasis is placed on the interaction of the farm household with off-farm or non-farm job markets.

Studies concerning the effects of non-farm employment opportunities on farm labor, production, and income can be traced back to 1960s and 1970s.[5] With long-term growth in non-farm sectors, it has been observed that agricultural households in many countries (especially the developed countries such as the United States and the European Union) are increasingly interacting with external labor markets either as a way of improving household income or as an option for income diversification. Several studies have documented that income from off-farm activities constitutes an increasingly important part of total household income for farmers.[6] For agricultural households in the United States, for example, it has been shown that there is a positive correlation between farm income variability and off-farm employment, and that off-farm labor earnings play a prominent role for income diversification (Mishra and Goodwin, 1997). Other interesting observations include that farm women's participation in the off-farm labor markets has been increasing and that the majority of farm women in the U.S. are now employed off the farm (Findeis, 2002). In light of the facts,[7] we pay particular attention to the behavior of a farm household in adjusting its labor supply between farm work and off-farm employment.

Our analytical framework extends the income-leisure model of Benjamin (1992), that treats family and hired labor as perfect substitutes. Benjamin tested empirically for the optimal decisions of farm households, and found empirical results in support of the separation hypothesis. In a model with homogeneous labor inputs and flexible off-farm job opportunities, Benjamin found that the optimal mix of family and hired labor is theoretically *indeterminate* (1992, p. 291). We show that this indeterminacy problem can be resolved by the heterogeneity approach in which family and hired labor are treated as separate inputs (Schultz, 1999). Moreover, we show that the imperfect substitutability of family and hired labor is not critical in undermining the separation proposition. One critical element to the separation between household production and consumption is the availability of off-farm employment opportunities.

The remainder of the paper is organized as follows. Section 2 presents a farm household model in which off-farm employment is flexible and the equilibrium in family and hired labor is unique. Section 3 presents a model with off-farm employment constraints. Section 4 concludes.

2. A model with flexible off-farm job opportunities

2.1. The analytical framework

Following the farm household literature, we adopt the traditional income-leisure approach to examine the labor supply and production decisions of a farm family. The household's preferences are defined over income (I) and leisure (L): $U = U(I, L)$. We assume this utility function is twice continuously differentiable and strictly quasi-concave, which implies that indifference curves are strictly convex.

With respect to farm production, we consider the case where there is imperfect substitutability between on-farm family and hired labor. This consideration parallels Schultz's (1999) observation that

the two labor inputs may not be good substitutes "because of differences in relevant skills and farm-specific management experience, or because incentive and monitoring costs differ in these tasks for family and hired labor" (p. 7).[8] For simplicity we assume that farm production is given by $Q = G(F, H; A)$, where Q represents a main agricultural output, F is on-farm family labor, H is hired-in labor, and A is fixed or exogenously given such as land. The production function is twice continuously differentiable and strictly concave in labor inputs, i.e.,

$$G_F = \frac{\partial G}{\partial F} > 0, G_H = \frac{\partial G}{\partial H} > 0, G_{FF} = \frac{\partial^2 G}{\partial F^2} < 0, G_{HH} = \frac{\partial^2 G}{\partial H^2} < 0,$$

$$\text{and } G_{FF}G_{HH} - G_{FH}^2 > 0, \text{ where } G_{FH} = G_{HF} = \frac{\partial^2 G}{\partial F \partial H} = \frac{\partial^2 G}{\partial H \partial F}.$$

These assumptions indicate that the positive marginal product of each labor input is subject to diminishing returns. Family and hired labor may be technologically complement ($G_{FH} > 0$) or substitute ($G_{FH} < 0$).

Given the assumption that family and hired-in labor are heterogeneous, there are two competitive labor markets: one for hired-in labor whose wage rate is w_h and the other for off-farm family labor whose wage rate is w_o. We assume that off-farm wage is higher than hiring-in wage, i.e., $w_o > w_h$. This assumption is consistent with the facts that farm households' participation in the off-farm labor markets and their off-farm earnings have been increasing (Mishra and Sandretto, 2002).

In this section, we focus the analysis on the case of a flexible off-farm work schedule. The household allocates its time between on-farm work (F), off-farm employment (M), and leisure (L), where $M = T - F - L$ and T is the household's total time endowment in a given period. Because of on-farm work and off-farm employment, there are two sources of labor incomes for the household. One is on-farm income, which is defined as farm revenues net of wage payments to hired-in labor, $y_f \equiv pG(F, H; A) - w_hH$, where p represents the competitive price of the farm product. The other source of income is off-farm labor earnings, defined as off-farm wage times off-farm labor supply, $E_o = w_oM = w_o(T - F - L)$. Total income of the household is then given as

$$I = [pG(F, H; A) - w_hH] + w_o(T - F - L) + Z, \tag{1}$$

where Z is non-labor income (e.g., a direct income payment from government) which is exogenously given.

Substituting Eq. (1) into the utility function yields

$$U = U(pG(F, H; A) - w_hH + w_o(T - F - L) + Z, L). \tag{2}$$

The objective of the household is to maximize utility by choosing F, H, and L. The first-order conditions (FOCs) are given, respectively, as

$$pG_F(F, H; A) - w_o = 0, \tag{3}$$

$$pG_H(F, H; A) - w_h = 0, \tag{4}$$

$$U_I(I, L)(-w_o) + U_L(I, L) = 0, \tag{5}$$

where $U_I = \frac{\partial U(.)}{\partial I} > 0$ and $U_L = \frac{\partial U(.)}{\partial L} > 0$.[9] Eq. (3) indicates that the household supplies labor to the farm up to the level where the

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[5] See, e.g., Nakajima (1969), Bowles (1970), and Yotopoulos and Lau (1974).
[6] See e.g., Anderson and Leiserson (1980), Rosenzweig (1988), Ahearn and Lee (1991), Jacoby (1993), Newman and Gertler (1994), and Mishra and Sandretto (2002).
[7] Technological improvements in the production of agricultural products have resulted in farmers either leaving production agriculture or finding part-time jobs in the non-farm sectors (see, e.g., Barkley, 1990; Gardner, 1992; Ahearn and Lee 1991). Changes in external economic conditions and government policies also contribute to the adjustments of farm households in labor supply, production, and consumption decisions. For contributions regarding the reallocation of labor between farm and non-farm work from a household's perspective see, e.g., Huffman (1976, 1980), Sumner (1982), Benjamin (1992), and Caillavet et al. (1994).

[8] There are several important studies that also treat hired labor as another variable input in farm production. See, e.g., Strauss (1986) and Huffman (1980, 1991).
[9] An alternative approach is to assume that the household has the following utility function: $U = U(X, L)$, where X is a Hicksian composite good whose price (p_X) is normalized to one. The budget constraint facing the household is $X + w_oL = pG(F, H; A) - w_hH - w_oF + w_oT + Z$, where the left-hand side of the equation is *household expenditures* on the two consumption goods, X and L, and the right-hand side of the equation is the *household full income constraint*. Solving for X, we have $X = pG(F, H; A) - w_hH + w_o(T - F - L) + Z$ which is analogous to Eq. (1). It follows that $U(X, L) = U(pG(F, H; A) - w_hH + w_o(T - F - L) + Z, L)$. The objective of the household is to choose F, H, and L that maximize $U(X, L)$. The FOCs are exactly the same as those in Eqs. (3)–(5). Thus, income in our model can also be expressed in terms of the Hicksian composite good (i.e., a numeraire good) whose price is one.

value of marginal product of on-farm family labor (VMP_F), pG_F, equals the competitive off-farm wage, w_o. That is, marginal returns from the on-farm work and off-farm employment are equalized. The shadow wage of on-farm family labor is thus measured by the off-farm wage. Eq. (4) indicates that the household hires in labor up to the level where its value of marginal product, pG_H, equals the hiring-in wage, w_h.[10]

Given the production technology and the competitive wages, the FOCs in Eqs. (3) and (4) determine the household's on-farm employment of family labor, F^*, and hired-in labor, H^*. This production decision of the farm household is thus independent of its preferences. The separation hypothesis remains valid despite the imperfect substitutability of family and hired labor. These findings contrast with Benjamin (1992), that separation "places no restriction on the mix of family and hired labor" (p. 290) and that there is a non-separation when family and hired labor are imperfect substitutes.

As for utility maximization, the FOC in Eq. (5) indicates that the household obtains the most preferred choice at the point where the marginal rate of substitution of leisure for income, $MRS_{LI}\left(=-\frac{dI}{dL}\right)=\frac{U_L}{U_I}$, equals the "competitive price" of leisure as measured by the off-farm wage, w_o. The household's optimal decision can be considered as being made in two steps: once F^* and H^* are determined by Eqs. (3) and (4), the optimal leisure time (denoted as L^*) is determined by Eq. (5). In other words, family labor is employed on the farm until its marginal product equals w_o. The family then directs the rest of its labor off-farm, while hired labor is hired in until its marginal product equals w_h.

Next, we show that the interior equilibrium is *unique* by examining the second-order conditions. It follows from the FOCs in Eqs. (3)–(5) that we have the Hessian determinant:

$$|D_3| = \begin{vmatrix} pG_{FF} & pG_{FH} & 0 \\ pG_{HF} & pG_{HH} & 0 \\ 0 & 0 & J \end{vmatrix}, \tag{6}$$

where

$$J = U_{II}(w_o)^2 - 2w_o U_{IL} + U_{LL}, U_{II} = \frac{\partial^2 U}{\partial I^2}, U_{IL} = \frac{\partial^2 U}{\partial I \partial L}, and U_{LL} = \frac{\partial^2 U}{\partial L^2}.$$

Given that $w_o = \frac{U_L}{U_I}$ (see the FOC in Eq. (5)), we rewrite the term J as follows:

$$J = U_{II}\left(\frac{U_L}{U_I}\right)^2 - 2\left(\frac{U_L}{U_I}\right)U_{IL} + U_{LL}$$
$$= \frac{1}{U_1^2}\left(U_{II}U_L^2 - 2U_I U_L U_{IL} + U_{LL}U_I^2\right) < 0. \tag{7}$$

The sign of J is unambiguously *negative* due to the strict convexity of indifference curves. The Hessian matrix is negative definite because

$$|D_1| = pG_{FF} < 0, |D_2| = p^2\left(G_{FF}G_{HH} - G_{FH}^2\right) > 0, and |D_3| = |D_2|J < 0 \tag{8}$$

Thus the interior solution is indeed unique. The model is complete in that it endogenously determines on-farm employment of family and hired labor (F^* and H^*), as well as leisure and off-farm labor supply (L^* and $M^* = T - F^* - L^*$). The optimal levels of output, on-farm income, and off-farm wage earnings are given, respectively, as

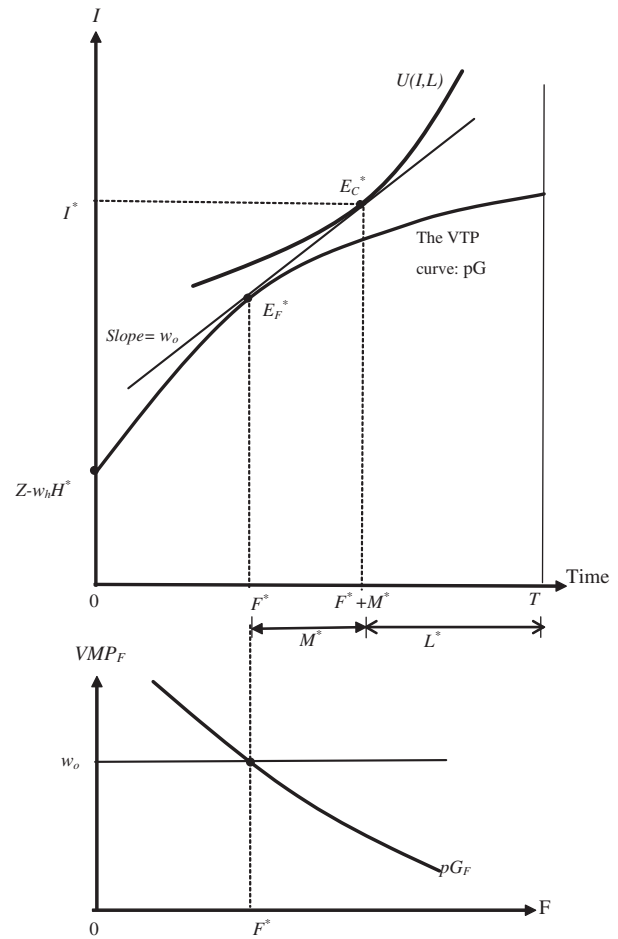$$Q^* = G(F^*, H^*; A), y_f^* = pG(F^*, H^*; A) - w_h H^*, and E_o^* = w_o(T - F^* - L^*).$$

Fig. 1. Time allocation decision of the agricultural household.

Fig. 1 presents a graphical illustration of the unique equilibrium for a farm household. In the upper panel, we have the value-of-total-product (VTP) curve which is determined by $pG(.)$. The vertical intercept of the VTP curve is $Z - w_h H^*$, which reflects non-labor income minus the total wage payment to hired-in labor. The household's optimal choice of production occurs at a point like E_F^* where the slope of the VTP curve, pG_F, equals the off-farm competitive wage, w_o. The household's optimal decisions on off-farm labor supply and leisure occur at a point like E_C^* where $MRS_{LI} = w_o$. In equilibrium, the amounts of time allocated to on-farm work and off-farm employment are given respectively by F^* and M^*, and the amount of leisure that the household consumes is L^*. Total family income (I^*) is the sum of on-farm income, off-farm labor earnings, and non-labor income, net of the total wage payment to hired labor. The lower panel illustrates the marginal condition for on-farm family labor.[11]

The imperfect substitutability of family and hired labor allows us to determine the equilibrium amounts of the two inputs uniquely. The model indicates that household production and consumption are separable. Despite such a separation, the household's on-farm family labor will be affected by changes in off-farm wage, so will its off-farm labor supply be affected by changes in hiring-in wage and the competitive price of the agricultural product. Furthermore, interactions between on-farm work and off-farm employment directly affect the composition of on-farm income and off-farm labor earnings. In what follows, we examine these questions.

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[10] It follows from the FOCs in (3) and (4) that if $w_o > w_h$ then $G_F > G_h$.

[11] The optimal level of hired labor is determined by the equilibrium condition $pG_H = w_h$, which is not shown in Fig. 1.

2.2. Comparative statics and its economic implications

To present a comparative static analysis, we take the total differential of the FOCs in Eqs. (3)–(5) and obtain the following:

$$\begin{bmatrix} pG_{FF} & pG_{FH} & 0 \\ pG_{HF} & pG_{HH} & 0 \\ 0 & 0 & J \end{bmatrix} \cdot \begin{bmatrix} dF^* \\ dH^* \\ dL^* \end{bmatrix} = \begin{bmatrix} -G_F dp + dw_o \\ -G_H dp + dw_h \\ K \end{bmatrix}, \tag{9}$$

where K is given as

$$K = [G(w_o U_{II} - U_{LI})]dp + [U_I + (w_o U_{II} - U_{LI})(T - F^* - L^*)]dw_o - (w_o U_{II} - U_{LI})H^* dw_h + (w_o U_{II} - U_{LI})dZ.$$

We first examine how changes in external economic conditions and government policies affect the household's decisions on on-farm work, off-farm employment, and leisure. We then examine the resulting impacts on household income and welfare.

2.2.1. Effects on labor and production decisions

2.2.1.1. Changes in non-labor income (Z). It is necessary to analyze the effect of changes in non-labor income in order to identify the condition under which leisure is a normal good. Holding constant all the exogenous variables except Z, we have from the system in Eq. (9) that

$$\frac{\partial F^*}{\partial Z} = \frac{\partial H^*}{\partial Z} = 0, \tag{10a}$$

$$\frac{\partial L^*}{\partial Z} = \frac{w_o U_{II} - U_{LI}}{J}. \tag{10b}$$

Eq. (10a) indicates that non-labor income does not affect on-farm family and hired labor. As a result, farm production will not be affected either.[12] Eq. (10b) indicates that the necessary and sufficient condition for leisure to be a normal good is

$$w_o U_{II} - U_{LI} < 0. \tag{10c}$$

Unless otherwise specified, we adopt this normality condition. Given that the equilibrium off-farm labor supply is $M^* = T - F^* - L^*$, it is straightforward to show that

$$\frac{\partial M^*}{\partial Z} = -\frac{\partial L^*}{\partial Z} < 0.$$

These results allow us to establish

Proposition 1. *In a competitive economy with no constraints on off-farm employment opportunities, a farm household that receives direct income payment from a governmentally funded program reduces its off-farm labor supply. However, the program does not generate any effect on farm production.*

Thus a policy change that reduces direct income payments in an era of tight government budgets affects leisure and off-farm labor supply of a farm household, but *not* its labor inputs and production. Although production and on-farm income are unaffected, farm households respond to lower income payments by increasing their off-farm labor supplies.

Proposition 1 may explain why after the Uruguay Round of GATT negotiations the emphasis of reforming agricultural production and trade shifted from price subsides to direct income payments. The shift in emphasis is consistent with the results that a direct income payment policy does not affect agricultural supply and hence does

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not generate any market price distortion like its counterpart of price support. This argument leads one to examine how the removal of a price support program (say, due to agricultural trade liberalization) affects the time allocation and production decisions of a farm household.

2.2.1.2. Changes in agricultural price (p). To analyze output price effects, we use Eq. (9) and drive the following:

$$\frac{\partial F^*}{\partial p} = \frac{p(-G_F G_{HH} + G_H G_{FH})}{|D_2|} > (=)(<) \, 0; \frac{\partial F^*}{\partial p} > 0 \text{ if } G_{FH} > 0; \tag{11a}$$

$$\frac{\partial H^*}{\partial p} = \frac{p(-G_H G_{FF} + G_F G_{HF})}{|D_2|} > (=)(<)0; \frac{\partial H^*}{\partial p} > 0 \text{ if } G_{FH} > 0; \tag{11b}$$

$$\frac{\partial L^*}{\partial p} = \frac{Q^*(W_o U_{II} - U_{LI})}{J} > 0, \text{if leisure is a normal good.} \tag{11c}$$

Given that $M^* = T - F^* - L^*$, we have

$$\frac{\partial M^*}{\partial p} = -\frac{dF^*}{dp} - \frac{dL^*}{dp} < (=)(>)0; \frac{\partial M^*}{\partial p} < 0 \text{ if } G_{FH} > 0. \tag{11d}$$

The effects of changes in output price on family and hired labor are, in general, indeterminate. If family and hired labor are complements, an increase in output price unambiguously causes both labor inputs to increase. The increase in output price leads the household to consume more leisure, with the result that off-farm labor supply decreases. If family and hired labor are substitutes, we cannot predict unambiguously the output price effects on the two inputs.

It comes as no surprise that farm production increases with output price, regardless of whether family and hired labor are complements or substitutes. Taking the derivative of output with respect to its price, using Eqs. (11a) and (11b), yields

$$\frac{\partial Q^*}{\partial p} = G_F \frac{\partial F^*}{\partial p} + G_H \frac{\partial H^*}{\partial p} = \frac{p\left[-G_{FF}(G_H)^2 + 2G_F G_H G_{FH} - G_{HH}(G_F)^2\right]}{|D_2|} > 0,$$

where the positive sign follows directly from the strict convexity of isoquants.

We summarize the results of the above analysis in the following proposition:

Proposition 2. *For the case in which flexible off-farm employment opportunities are available to a farm household, we have the following results: (i) If family and hired labor are complements, both labor inputs increase with output price; (ii) Output supply curve is upward-sloping; (iii) An increase in output price increases leisure, but the output price effect on the household's off-farm labor supply is generally indeterminate, depending on the technological relationship between family and hired labor.*

Proposition 2 implies that an agricultural price subsidy program has an ambiguous effect on the labor decisions of a farm household, but the program's effect on farm production is unambiguously positive. This may explain why government intervention in agriculture in the form of price support and/or export subsidies in Western developed countries during the 1980s and early 1990s had resulted in substantial increase in the outputs of agricultural products. The resulting market price distortions had triggered GATT/WTO to reform agricultural production and trade after the Uruguay Round of Multi-lateral Trade Negotiations. Direct income payments were therefore considered as an alternative policy for price support.

2.2.1.3. Changes in off-farm wage (w_o). As mentioned in Section 1, several empirical studies have documented the increasing interactions of

farm households with non-farm labor markets. Using the system in Eq. (9), we determine the effects of changes in off-farm wage on labor decisions as follows:

$$\frac{\partial F^*}{\partial w_o} = \frac{pG_{HH}}{|D_2|} < 0; \tag{12a}$$

$$\frac{\partial H^*}{\partial w_o} = \frac{-pG_{HF}}{|D_2|} < (>)0; \frac{\partial H^*}{\partial w_o} < 0 \text{ if } G_{HF} > 0; \tag{12b}$$

$$\frac{\partial L^*}{\partial w_o} = \frac{U_I + (w_o U_{II} - U_{LI})(T - F^* - L^*)}{J} < (=)(>)0; \tag{12c}$$

$$\frac{\partial M^*}{\partial w_o} = -\frac{\partial F^*}{\partial w_o} - \frac{\partial L^*}{\partial w_o} < (=)(>)0. \tag{12d}$$

In view of the results in Eqs. (12a)–(12d), we have

Proposition 3. *An increase in off-farm wage encourages a farm household to reduce on-farm family labor. Household demand for hired labor may not fall, unless family and hired labor are complements. The effects on leisure and off-farm labor supply depend on whether leisure is a normal or an inferior good to the household.*

Because an increase in off-farm wage has a negative effect on on-farm family labor, one interesting issue is how the wage increase affects the off-farm labor supply of farm household members—especially spouses. Becker (1981) indicated the trend in the past several decades that increasing job opportunities and rising wages for women have significantly increased women's participation in the paid labor markets. In an interesting empirical study, Findeis (2002) found that the majority of farm women in the U.S. are now employed off-farm. Although a bargaining setup with an interaction of labor supplies between spouses would be more appropriate to address the issue,[13] our simple household model may provide a heuristic explanation. In view of the result in Eq. (12d), we find that $\partial M^*/\partial w_o$ is positive if, and only if, $-\partial F^*/\partial w_o$ is greater than $\partial L^*/\partial w_o$. That is, with an increase in off-farm wage, if the reallocation of family labor from on-farm work to off-farm employment *exceeds* demand for leisure, off-farm labor supply will increase.[14]

Matshe and Young (2004) analyzed the on-farm and off-farm labor decisions of small-scale agricultural household members in Zimbabwe. They found that variables such as gender and education of members in a farm household have different effects on labor market participation and the number of hours supplied to work. Serra et al. (2005) examined various effects that 1996 U.S. farm policy reforms had on a sample of Kansas farmers. The authors found that the implementation of fixed, decoupled payments tended to reduce the likelihood of off-farm labor market participation. The reduction in agricultural price supports tended to increase the motivation of farmers to work off the farm. The overall effect on off-farm employment participation appeared not to have been large. Applying surveyed data of 276 Iowa farmers to a two-household model, Kwon et al. (2006) found that for an unforeseen adverse shock to the farm operations, farmers' wives are more likely to join off-farm labor market. Farm husbands were less sensitive to transitory farm income changes, thus less likely to switch to off-farm labor market. But for

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[13] This point suggests the need for future research to develop agricultural household bargaining models that allow for (i) an interaction of the labor supply decisions of husband and wife with distinct preferences and (ii) the wife's decision to participate in off-farm labor markets. For farm household models that take into account labor supplies of husbands and wives or women's participation in the labor force see, e.g., Huffman (1976), Huffman and Lange (1989), Schultz (1990a, 1990b), Tokle and Huffman (1991), and Udry (1996).

[14] The sign of $\partial L^*/\partial w_o$ in Eq. (12c) is, in general, indeterminate, depending on the Hicksian substitution effect and the associated income effect. Here we pay attention to off-farm labor supply in interaction with leisure demand when off-farm wage increases.

the case when the permanent farm income was expected to rise, both husbands and wives were less likely to work off-farm. The authors further concluded that farm households adjusted their consumption of leisure to replace transitory lost in their farm income.

2.2.1.4. Changes in hiring-in wage (w_h). Hired labor is frequently assumed to be a perfect substitute for family labor in the literature (Benjamin, 1992). This assumption makes it difficult to determine a unique solution for hired labor and on-farm family labor. In the model of labor input heterogeneity we consider, we have from Eq. (9) that the effects of changes in hiring-in wage are:

$$\frac{\partial F^*}{\partial w_h} = \frac{-pG_{FH}}{|D_2|} < (=)(>) \text{ 0 if } G_{FH} > (=)(<) 0; \tag{13a}$$

$$\frac{\partial H^*}{\partial w_h} = \frac{pG_{FF}}{|D_2|} < 0; \tag{13b}$$

$$\frac{\partial L^*}{\partial w_h} = \frac{-H^*(w_o U_{II} - U_{LI})}{J} < 0; \tag{13c}$$

$$\frac{\partial M^*}{\partial w_h} = -\frac{\partial F^*}{\partial w_h} - \frac{\partial L^*}{\partial w_h} > (=)(<)0. \tag{13d}$$

First, the effect of an increase in hiring-in wage on on-farm family labor is negative or positive, depending on whether family and hired labor are complements or substitutes. Second, demand for hired labor decreases its wage. Third, an increase in hiring-in wage lowers leisure demand, but the effect on off-farm labor supply is indeterminate. Only when family and hired labor are complements will off-farm labor supply increase with hiring-in wage. But in this case farm production decreases because both on-farm family and hired labor decrease.

2.2.2. Effects on total household income and welfare

To analyze how changes in output price affect household income, we take the derivative of income in Eq. (1) with respect to p, and evaluate the resulting expression at the equilibrium, (F^*, H^*, L^*), to get

$$\frac{\partial I^*}{\partial p} = (pG_F - w_o)\frac{\partial F^*}{\partial p} + (pG_H - w_h)\frac{\partial H^*}{\partial p} + Q^* - w_o\frac{\partial L^*}{\partial p} = Q^* - w_o\frac{\partial L^*}{\partial p}. \tag{14a}$$

If leisure is an *inferior* good such that $\partial L^*/\partial p$ is negative (see Eq. (11c)), the sign of $\partial I^*/\partial p$ is unambiguously positive. But if leisure is a normal good such that $\partial L^*/\partial p$ is positive, there are three possibilities:

$$\frac{\partial I^*}{\partial p} > (=)(<) \text{ 0 if } Q^* > (=)(<)w_o\frac{\partial L^*}{\partial p}. \tag{14b}$$

A change in output price generates two conflicting effects on total household income. A one-dollar increase in output price, for example, raises on-farm income by an amount equal to Q^*. This price increase encourages a household to consume more leisure and hence lower its off-farm income by an amount equal to $w_o(\partial L^*/\partial p)$. If Q^* is greater than (equal to) (less than) $w_o(\partial L^*/\partial p)$, total household income increases (remains the same) (decreases). This explains why the output price effect on total household income $\partial I^*/\partial p$ is, in general, indeterminate.

Despite the ambiguous relationship between total income and output price, a decrease (an increase) in output price lowers (raises) household utility. To see this, we take the derivative of utility with respect to p and use the FOC in Eq. (5) and the result in Eq. (14a) to obtain the following:

$$\frac{\partial U^*}{\partial p} = U_I\frac{\partial I^*}{\partial p} + U_L\frac{\partial L^*}{\partial p} = U_I\left(Q^* - w_o\frac{\partial L^*}{\partial p}\right) + U_L\frac{\partial L^*}{\partial p} = U_I Q^* > 0. \tag{14c}$$

We thus have

Proposition 4. *A decrease in output price unambiguously lowers the utility of a farm household. The household's total income may increase if the family significantly increases off-farm labor supply by lowering its leisure.*

Proposition 4 indicates the role of off-farm employment in increasing total household income. Another implication concerns the relationship between changes in money income and changes in utility (i.e., welfare). In the farm household model in which income is endogenous and leisure is a normal good, changes in money income and changes in utility may not be "synchronized." This suggests that, under certain circumstances, money income may be inadequate in serving as a measure to reflect the actual change in utility or welfare.

Next, we discuss the effect of changes in off-farm wage on total household income. Taking the derivative of income in Eq. (1) with respect to w_o, evaluating the resulting expression at (F^*, H^*, L^*), yields

$$\frac{\partial I^*}{\partial w_o} = (pG_F - w_o)\frac{\partial F^*}{\partial w_o} + (pG_H - w_h)\frac{\partial H^*}{\partial w_o} - w_o\frac{\partial L^*}{\partial w_o} + (T - F^* - L^*)$$
$$= -w_o\frac{\partial L^*}{\partial w_o} + M^*. \tag{15a}$$

This sign is indeterminate. The sufficient condition for $\partial I^*/\partial w_o$ to be positive is

$$M^* > w_o\frac{\partial L^*}{\partial w_o} \text{ or } \frac{M^*}{L^*} > \varepsilon_{L^*, w_o}\left(\equiv \frac{\partial L^*}{\partial w_o}\frac{w_o}{L^*}\right). \tag{15b}$$

For a one-dollar increase in w_o, *ceteris paribus*, total household income increases by an amount equal to the amount of time supplied to off-farm work, M^*. But the increased wage also leads the household to consume more leisure, with the result that the amount of income forgone is equal to $w_o(\partial L^*/\partial w_o)$. If M^* is greater than $w_o(\partial L^*/\partial w_o)$, total income increases.[15] An alternative interpretation is that total income increases if the ratio of M^* over L^* exceeds the elasticity of demand for leisure with respect to off-farm wage.

With flexible off-farm employment, one question of interest concerns whether a household's utility will increase with the off-farm wage. To see this, we take the derivative of utility with respect to w_o, using the FOC in Eq. (5) that $U_I w_o = U_L$ and Eq. (15a), to get

$$\frac{\partial U^*}{\partial w_o} = U_I\frac{\partial I^*}{\partial w_o} + U_L\frac{\partial L^*}{\partial w_o} = U_I\left(-w_o\frac{\partial L^*}{\partial w_o} + M^*\right) + U_L\frac{\partial L^*}{\partial w_o} = U_I M^* > 0. \tag{15c}$$

It follows from Eqs. (15a) and (15c) that total household income may be decreasing when household utility is increasing. This possibility arises when the household significantly reduces on-farm labor supply by consuming more leisure (see Fig. 2). We therefore have

Proposition 5. *An increase in off-farm wage is welfare-improving if members of a farm household are employed off the farm, ceteris paribus. Total household income may increase or decrease, depending on the family's decisions on off-farm labor supply and leisure demand.*

As for the impact on household income resulting from changes in hiring-in wage, we have

$$\frac{\partial I^*}{\partial w_h} = (pG_F - w_o)\frac{\partial F^*}{\partial w_h} + (pG_H - w_h)\frac{\partial H^*}{\partial w_h} - H^* - w_o\frac{\partial L^*}{\partial w_h} = -H^* - w_o\frac{\partial L^*}{\partial w_h}. \tag{16}$$

[15] Chinn (1979) found that off-farm income in Taiwan was the major source of rising agricultural household incomes in the 1970s, even though during the same period real agricultural income also increased because of significant increases in agricultural productivity.
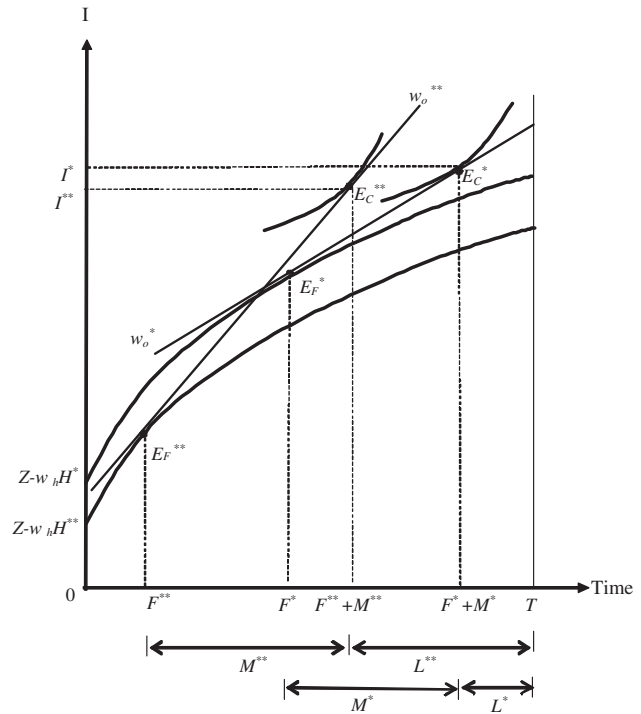

Fig. 2. The case of an increase in utility with a decrease in total income (when the off-farm wage increases).

If leisure is a normal good such that $\partial L^*/\partial w_h$ is negative, the sign of $\partial I^*/\partial w_h$ is indeterminate. Nevertheless, total household income may increase when the following sufficient condition is satisfied:

$$\frac{\partial I^*}{\partial w_h} > 0 \text{ if } w_o\left(-\frac{\partial L^*}{\partial w_h}\right) > H^*.$$

For a one-dollar increase in w_h, total income decreases by an amount equal to the amount of hired labor, H^*. But the increase in hiring-in wage causes leisure to decrease and off-farm labor supply to increase. If the resulting increase in off-farm labor earnings $w_o(-\partial L^*/\partial w_h)$ is greater than H^*, total household income increases. The hiring-in wage effect on total income is indeterminate, but its effect on welfare is unambiguously negative. That is, $\partial U^*/\partial w_h = -H^* < 0$.

Next, we discuss what effect a change in non-labor income has on total household income. Unlike farm production and on-farm income, total household income is *not* independent of non-labor income. This is because leisure is responsive to changes in non-labor income. Taking the derivative of I^* with respect to Z yields

$$\frac{\partial I^*}{\partial Z} = (pG_F - w_o)\frac{\partial F^*}{\partial Z} + (pG_H - w_h)\frac{\partial H^*}{\partial Z} + 1 - w_o\frac{\partial L^*}{\partial Z} = 1 - w_o\frac{\partial L^*}{\partial Z}. \tag{17}$$

If leisure is a normal good ($\partial L^*/\partial Z > 0$), the sign of $\partial I^*/\partial Z$ cannot be determined unambiguously. That is,

$$\frac{\partial I^*}{\partial Z} > (=)(<) 0 \text{ if } 1 > (=)(<) w_o\frac{\partial L^*}{\partial Z}.$$

For a one-dollar increase in non-labor income, if the amount of income forgone, $w_o(\partial L^*/\partial Z)$, is less than (equal to) (more than) that one dollar, total household income increases (remains unchanged) (decreases). Interestingly, household utility increases with non-labor income because $\partial U^*/\partial Z = U_I > 0$.

2.2.3. Effects on on-farm income and off-farm labor earnings

The empirical studies of Rosenzweig (1988) and many others documented the importance of off-farm income to farm households. One issue of interest concerns how the composition of total household income is affected by changes in external economic conditions. Given that on-farm gross income is $y_f^* = pQ(F^*, H^*) - w_h H^*$, we have

$$\frac{\partial y_f^*}{\partial p} = pG_F \frac{\partial F^*}{\partial p} + G^* > (=)(<) 0; \frac{\partial y_f^*}{\partial p} > 0 \quad \text{if } G_{FH} > 0; \tag{18a}$$

$$\frac{\partial y_f^*}{\partial w_o} = pG_F \frac{\partial F^*}{\partial w_o} + (pG_H - w_h)\frac{\partial H^*}{\partial w_o} = pG_F \frac{\partial F^*}{\partial w_o} < 0; \tag{18b}$$

$$\frac{\partial y_f^*}{\partial w_h} = pG_F \frac{\partial F^*}{\partial w_h} - H^* > (=)<0; \frac{\partial y_f^*}{\partial w_h} < 0 \quad \text{if } G_{FH} > 0; \tag{18c}$$

$$\frac{\partial y_f^*}{\partial Z} = pG_F \frac{\partial F^*}{\partial Z} + (pG_H - w_h)\frac{\partial H^*}{\partial Z} = 0. \tag{18d}$$

We thus have

Proposition 6. *On-farm income increases with output price if family and hired labor are complements. An increase in off-farm wage causes the on-farm income to fall. Also, the on-farm income is a decreasing function of hiring-in wage if family and hired labor are complements. Changes in non-labor income, however, do not generate any effect on on-farm income.*

With respect to the effects on off-farm labor earnings, $E_o^* = w_o M^*$, we have

$$\frac{\partial E_o^*}{\partial p} = w_o \frac{dM^*}{dp} < (=)(>) 0; \frac{\partial E_o^*}{\partial p} < 0 \quad \text{if } G_{FH} > 0; \tag{19a}$$

$$\frac{\partial E_o^*}{\partial w_o} = M^* + w_o \frac{\partial M^*}{\partial w_o} > (=)(<) 0; \frac{\partial E_o^*}{\partial w_o} > 0 \quad \text{if } \eta \equiv \frac{\partial M^*}{\partial w_o}\frac{w_0}{M^*} > -1; \tag{19b}$$

$$\frac{\partial E_o^*}{\partial w_h} = w_o \frac{\partial M^*}{\partial w_h} > (=)(<) 0; \tag{19c}$$

$$\frac{\partial E_o^*}{\partial Z} = w_o \frac{\partial M^*}{\partial Z} < 0. \tag{19d}$$

The implications of the derivatives are summarized in the following proposition:

Proposition 7. (i) *In the face of a decrease in agricultural price, a farm household can increase its off-farm labor earnings through a reallocation of labor from on-farm work to off-farm employment. The sufficient condition under which off-farm labor earnings increases as product price decreases is when family and hired labor are complements.*

(ii) *When the off-farm labor supply curve is upward-sloping, an increase in off-farm wage raises off-farm labor earnings.*

(iii) *The effect of an increase in hiring-in wage on off-farm labor earnings is indeterminate.*

(iv) *An increase in non-labor income lowers off-farm labor supply, with the consequence that off-farm labor earnings decrease.*

Having discussed the economic implications for the case where off-farm employment opportunities are flexible, we proceed to examine the case where the availability of off-farm employment to a farm household is limited.

3. Considering off-farm employment constraints

3.1. A constrained-optimization framework

Our aim in this section is to analyze how the inflexibility of an off-farm work schedule affects a household's time allocation decisions, income, and utility. Let the constrained off-farm work time be exogenously fixed as $M = \bar{M}$. As such, leisure time and total household income become

$$L = T - F - \bar{M}, \tag{20}$$

$$I = pG(F, H; A) - w_h H + w_o \bar{M} + Z. \tag{21}$$

Substituting Eqs. (20) and (21) into the household's utility function yields

$$U = U\big(pG(F, H; A) - w_h H + w_o \bar{M} + Z, T - F - \bar{M}\big). \tag{22}$$

The FOCs for utility maximization with respect to F and H are given, respectively, as

$$pG_F(F, H; A) = \frac{U_L(I, L)}{U_I(I, L)}, \tag{23a}$$

$$pG_H(F, H; A) - w_h = 0. \tag{23b}$$

Eq. (23a) indicates that on-farm family labor is optimally chosen when its value of marginal product, pG_F, equals the marginal rate of substitution of leisure for income, $MRS_{LI}(= U_L/U_I)$. This optimal decision rule is different from the flexible off-farm employment case discussed in Section 2. Eq. (23b) is the usual marginal condition for hired labor. These two FOCs determine the equilibrium on-farm family and hired labor, denoted respectively by $\tilde{F}$ and $\tilde{H}$. Having determined $\tilde{F}$, the optimal consumption of leisure (denoted as $\tilde{L}$) is $\tilde{L} = T - \tilde{F} - \bar{M}$. Inspection of the FOCs reveals that decisions on labor inputs and production are *not* independent of household preferences. This implies that off-farm employment constraints are critical to the validity of the separation proposition.

With a binding constraint on off-farm work time, farm shadow wage may no longer be identical to off-farm wage. If a household has a strong (weak) preference over on-farm work, farm shadow wage is likely to be greater (less) than the off-farm wage. Fig. 3 presents a graphical interpretation of such a constrained equilibrium. In the upper panel, the exogenous off-farm work time $\bar{M}$ is first deducted from the total time endowment T. The off-farm wage w_o is given by the slope of the straight line connecting the origin 0 with point 0′. Point 0′ serves as a new origin to measure on-farm family labor $\tilde{F}$ on the horizontal axis.[16] Originating from point 0′, we draw a vale-of-total product (VTP) curve, i.e., $pG(.)$. The vertical intercept of the curve is $Z - w_h \tilde{H}$, which measures non-labor income net of wage payments to hired labor. The household's optimal choice of income and leisure occurs at a point like E_3, where the VTP curve is tangent to the highest indifference curve possible. At point E_3, the farm shadow price, measured by the value of marginal product of family labor VMP_F, is *less* than the off-farm wage w_o. For alternative

[16] Fig. 3 contrasts with Fig. 2 in Benjamin (1992, p. 293) where the optimal mix of family and hired labor is *indeterminate*. In analyzing the case of a binding constraint on off-farm employment, Benjamin (1992) showed that there is non-separation when family and hired labor are characterized by different efficiencies. But a farm household cannot determine unambiguously its family labor to be employed on the farm, however. Treating family and hired labor as separate inputs, we show that these labor inputs are uniquely determined. We further determine how on-farm family and hired labor change in response to changes in external economic conditions.
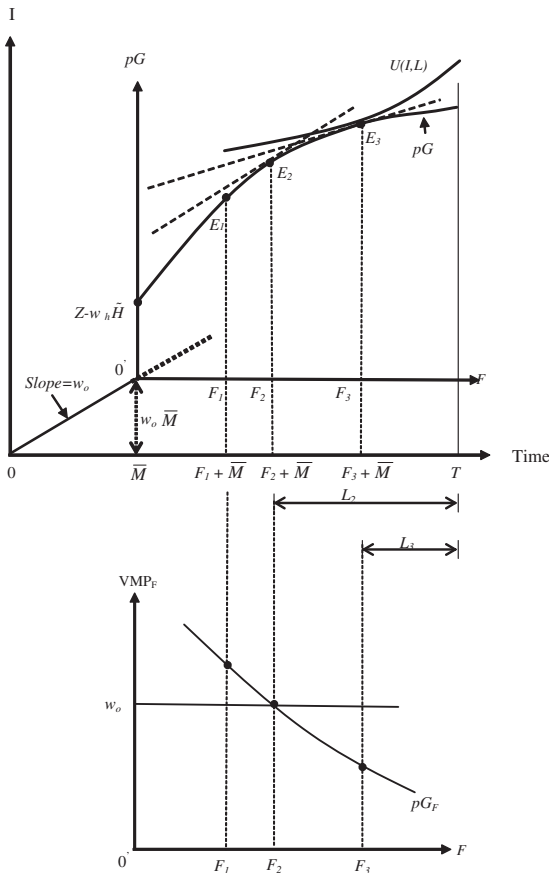
Fig. 3. Labor and production decisions in the presence of off-farm employment constraints.

household preferences, equilibrium may occur at a point like E_1 where the farm shadow wage is *greater* than the off-farm wage.[17]

It is necessary to check the second-order sufficient conditions for the constrained equilibrium. The Hessian determinant (denoted as $|S|$) is:

$$|S| = \begin{vmatrix} R & U_I pG_{FH} \\ pG_{HF} & pG_{HH} \end{vmatrix}, \text{ where } R = U_I pG_{FF} + \frac{1}{U_I^2}\left(U_L^2 U_{II} - 2U_I U_L U_{IL} + U_I^2 U_{LL}\right). \tag{24}$$

Diminishing marginal returns to on-farm family labor ($G_{FF} < 0$) and the strict quasi-concavity of utility imply that the value of R is strictly negative. Strict concavity of the production function further implies that the Hessian is negative definite because

$$R < 0 \quad \text{and} \quad |S| = U_I p^2 \left(G_{FF}G_{HH} - G_{FH}^2\right) + \frac{pG_{HH}}{U_I^2}\left(U_L^2 U_{II} - 2U_I U_L U_{IL} + U_I^2 U_{LL}\right) > 0.$$

Thus the interior solution is unique.

3.2. Comparative statics and its economic implications

Next, we examine how the farm household adjusts its optimal decision to changes external conditions. Taking the total differential of the FOCs in Eqs. (23a) and (23b) yields

$$\begin{bmatrix} R & pU_I G_{FH} \\ pG_{HF} & pG_{HH} \end{bmatrix}\begin{bmatrix} dF \\ dH \end{bmatrix} = \begin{bmatrix} N \\ -G_H dp + dw_h \end{bmatrix}, \tag{25}$$

---

[17] Only when household preferences are such that the equilibrium occurs at point like E_2 will the farm shadow wage coincide with the off-farm wage. Even for this special case, the exogenous $\bar{M}$ is not necessarily identical to the optimal off-farm work time (M^*) discussed in Section 2.

where the term R is given by Eq. (24) and the term N is defined as follows:

$$N = [-U_I G_F + Q(U_{LI} - pG_F U_{II})dp + \bar{M}(U_{LI} - pG_F U_{II})dw_o + w_o(U_{LI} - pG_F U_{II})d\bar{M}$$
$$-H(U_{LI} - pG_F U_{II})dw_h + (U_{LI} - pG_F U_{II})dZ.$$

In the subsequent analysis, we investigate equilibrium adjustments in the labor and production decisions of the household in response to external economic conditions. We then discuss the resulting impacts on household income and utility.

3.2.1. Effects on labor and production decisions

3.2.1.1. Changes in non-labor income (Z). As in Section 2, we first identify the necessary and sufficient condition for leisure to be a normal good. Given that $\tilde{L} = T - \bar{M} - \tilde{F}$, we have

$$\frac{\partial \tilde{F}}{\partial Z} = -\frac{\partial \tilde{L}}{\partial Z}. \tag{26a}$$

If leisure is a normal good ($\partial \tilde{L}/\partial Z > 0$), we have from Eq. (26a) that

$$\frac{\partial \tilde{F}}{\partial Z} < 0, \tag{26b}$$

which implies that an increase in non-labor income negatively affects on-farm labor supply. Next, we have from Eq. (25) that

$$\frac{\partial \tilde{F}}{\partial Z} = \frac{pG_{HH}(U_{LI} - pG_F U_{II})}{|S|}. \tag{26c}$$

Using Eqs. (26a)–(26c) and noting that $|S| > 0$ and $G_{HH} < 0$, we have the necessary and sufficient condition for leisure to be a normal good as follows:

$$(U_{LI} - pG_F U_{II}) > 0. \tag{26d}$$

Unless otherwise specified, we assume that this normality condition holds.

It follows from Eq. (25) that

$$\frac{\partial \tilde{H}}{\partial Z} = \frac{-pG_{HF}(U_{LI} - pG_F U_{II})}{|S|} > (<) \, 0 \text{ if } G_{HF} < (>) \, 0. \tag{26e}$$

Given that on-farm family labor decreases with non-labor income (see Eq. (26b)), if farm technology is such that family and hired labor are substitutes ($G_{HF} < 0$), the sign of $d\tilde{H}/dZ$ is positive. In this case, demand for hired labor increases with non-labor income, but farm production cannot be determined unambiguously. If farm technology is such that family and hired labor are complements ($G_{HF} > 0$), the sign of $d\tilde{H}/dZ$ is negative. In this case, hired labor and farm production unambiguously decrease with non-labor income. These findings contrasts with the case of flexible off-farm employment discussed in Section 2 where changes in non-labor income do *not* affect (i) on-farm employment of family and hired labor and (ii) farm production. In the presence of off-farm job constraints, a policy prescription that reductions in direct income payments do not affect farm production and on-farm income will no longer be valid.

Woldehanna et al. (2000) examined off-farm work decision, using an unbalanced panel of 4110 observations during 1971 to 1993. Their results indicated that non-labor income, on-farm labor supplied by other household members, and agricultural education do not have significant influence on off-farm work decision. Also, they discovered that rationing and unexpected transaction costs inhibited farm household to participate off-farm work. Furthermore, the positive

impacts on off-farm working decision could be found in family size and general education, but these two factors did not response to the level of off-farm labor income. In a recent contribution, Hennessy and Rehman (2008) investigated the interaction between government subsidies and farmers' time allocation decisions in Irish. Based on the Irish National Farm Survey dataset for 2002, the authors discovered that direct payment made it more likely for farmers to participate in the off-farm job market which could lead to an increase in household wealth. But for the case in which farm income decreased, the likelihood of looking for off-farm employment could increase.

3.2.1.2. Changes in agricultural price (p). With respect to output price effects, we use Eq. (25) to drive the following:

$$\frac{\partial \tilde{F}}{\partial p} = \frac{pG_{HH}\left[-U_I G_F + \tilde{Q}(U_{LI} - pG_F U_{II})\right] + pU_I G_H G_{FH}}{|S|} > (=)(<)\ 0; \quad (27a)$$

$$\frac{\partial \tilde{H}}{\partial p} = \frac{-G_H R - pG_{HF}\left[-U_I G_F + \tilde{Q}(U_{LI} - pG_F U_{II})\right]}{|S|} > (=)<0; \quad (27b)$$

$$\frac{d\tilde{L}}{dp} = -\frac{\partial \tilde{F}}{\partial p} > (=)(<)\ 0. \quad (27c)$$

Unless leisure is an inferior good and $G_{HF} > 0$ such that $d\tilde{F}/dp > 0$ and $d\tilde{H}/dp > 0$, the output price effects on $\tilde{F}$, $\tilde{H}$, and $\tilde{L}$ are indeterminate. It is then interesting to see whether or not the output supply curve remains to be upward-sloping. The effect of changes in price on output is:

$$\frac{\partial \tilde{Q}}{\partial p} = G_F \frac{\partial \tilde{F}}{\partial p} + G_H \frac{\partial \tilde{H}}{\partial p} = \frac{pU_I\left(-G_{HH}G_F^2 + 2G_F G_H G_{FH} - G_{FF}G_H^2\right)}{|S|}$$
$$- \frac{G_H^2}{U_I^2|S|}\left(U_{II}U_L^2 - 2U_I U_L U_{IL} + U_{LL}U_I^2\right) + \frac{p\tilde{Q}(G_F G_{HH} - G_H G_{HF})(U_{LI} - pG_F U_{II})}{|S|}. \quad (27d)$$

Unlike the unconstrained case, the sign of $\partial \tilde{Q}/\partial p$ can no longer be determined unambiguously. The *sufficient* conditions for the output supply curve to slopes upward are: (i) family and hired labor are complements ($G_{HF} > 0$) and (ii) leisure demand is inferior ($U_{LI} - pG_F U_{II} < 0$). Given that $\bar{M}$ is fixed, the farm household may respond to an output price increase by increasing its on-farm family labor. This can be achieved by reducing demand from leisure. If both family and hired labor are complements (condition (i)), farm production, on-farm income, and total household income will increase. In this case, there is a negative relationship between household income and leisure (condition (ii)) so that the output supply curve is upward-sloping.

In analyzing the on-farm and off-farm labor decisions of small-scale agricultural household members in Zimbabwe, Matshe and Young (2004) indicated the importance of farm household characteristics such as land area accessible to the family, assets, and the agricultural product prices in affecting the labor market participation decisions of rural household members.

3.2.1.3. Changes in off-farm wage (w_o). Next, we have from Eq. (25) that

$$\frac{\partial \tilde{F}}{\partial w_o} = \frac{pG_{HH}\bar{M}(U_{LI} - pG_F U_{II})}{|S|} = \bar{M}\frac{\partial \tilde{F}}{\partial Z} < 0; \quad (28a)$$

$$\frac{\partial \tilde{H}}{\partial w_o} = \frac{-pG_{HF}\bar{M}(U_{LI} - pG_F U_{II})}{|S|} = \bar{M}\frac{\partial \tilde{H}}{\partial Z} > (<)\ 0\ \text{if}\ G_{HF} < (>)0; \quad (28b)$$

$$\frac{\partial \tilde{L}}{\partial w_o} = -\frac{\partial \tilde{F}}{\partial w_o} > 0. \quad (28c)$$

With $\bar{M}$ being exogenously fixed, an increase in off-farm wage causes on-farm family labor to fall. This is because of an increase in leisure. Consequently, if family and hired labor are substitutes (complements), demand for hired labor increases (decreases).

3.2.1.4. Changes in hiring-in wage (w_h). With respect to the effects of changes in hiring-in wage, we have from Eq. (25) that

$$\frac{\partial \tilde{F}}{\partial w_h} = \frac{-\tilde{H}pG_{HH}(U_{LI} - pG_F U_{II}) - pU_I G_{FH}}{|S|} > (=)(<)0; \frac{\partial \tilde{F}}{\partial w_h} > 0\ \text{if}\ G_{HF} < 0; \quad (29a)$$

$$\frac{\partial \tilde{H}}{\partial w_h} = \frac{R + \tilde{H}pG_{HF}(U_{LI} - pG_F U_{II})}{|S|} < (=)(>)0; \frac{\partial \tilde{H}}{\partial w_h} < 0\ \text{if}\ G_{HF} < 0; \quad (29b)$$

$$\frac{\partial \tilde{L}}{\partial w_h} = -\frac{\partial \tilde{F}}{\partial w_h} < (=)(>)0; \frac{\partial \tilde{L}}{\partial w_h} < 0\ \text{if}\ G_{HF} < 0. \quad (29c)$$

For the case where family and hired labor are substitutes ($G_{HF} < 0$), an increase in hiring-in wage causes on-farm family labor to increase. Both hired labor and leisure will decrease.

3.2.1.5. Changes in Off-farm Work Time ($\bar{M}$). As for the effects of a change in off-farm work time, we have from Eq. (25) that

$$\frac{\partial \tilde{F}}{\partial \bar{M}} = \frac{pG_{HH}w_o(U_{LI} - pG_F U_{II})}{|S|} = w_o \frac{\partial \tilde{F}}{\partial \bar{M}} < 0; \quad (30a)$$

$$\frac{\partial \tilde{H}}{\partial \bar{M}} = \frac{-pG_{HF}w_o(U_{LI} - pG_F U_{II})}{|S|} = w_o \frac{\partial \tilde{H}}{\partial Z} > (<)\ 0\ \text{if}\ G_{HF} < (>)0; \quad (30b)$$

$$\frac{\partial \tilde{L}}{\partial \bar{M}} = -1 - \frac{\partial \tilde{F}}{\partial \bar{M}} > (<)0. \quad (30c)$$

Interestingly, an increase in $\bar{M}$ has a negative effect on on-farm family labor and a positive effect on consuming leisure. If family and hired labor are substitutes (complements), demand for hired labor increases (decreases). The effect on leisure is ambiguous, however.

We summarize these findings in the following proposition:

Proposition 8. *In the presence of a binding constraint on off-farm employment, household production and consumption are no longer separable. Consequently, we have the following results (i) The effects of a change in agricultural price on labor input decisions, leisure demand, and farm production can no longer be determined unambiguously; (ii) On-farm family labor, hired labor, and farm production are no longer independent of non-labor income; (iii) Demand for hired labor may not be a decreasing function of the hiring-in wage unless family and hired labor are substitutes; and (iv) An exogenous increase in off-farm work time has a negative effect on on-farm family labor.*

3.2.2. Effects on total household income and welfare

Next, we examine various effects on income and utility. Given that total household income is $\tilde{I} = \tilde{y}_f + w_o \bar{M} + Z$, where $\tilde{y}_f (= pG(\tilde{F}, \tilde{H}; A) - w_h \tilde{H})$ is on-farm gross income, we have

$$\frac{\partial \tilde{I}}{\partial p} = \frac{\partial \tilde{y}_f}{\partial p} = \tilde{Q} + pG_F \frac{\partial \tilde{F}}{\partial p} + (pG_H - w_h)\frac{\partial \tilde{H}}{\partial p} = \tilde{Q} + pG_F \frac{\partial \tilde{F}}{\partial p} > (=)(<)0.$$

The output price effect on total income (or on-farm gross income) is indeterminate because the derivative $\partial \tilde{F}/\partial p$ is ambiguous in sign (see Eq. (27a)). This finding suggests that the efficacy of government price subsidies in raising total household income is indeterminate unless the following sufficient condition is satisfied:

$$\tilde{Q} > -pG_F(\partial \tilde{F}/\partial p).$$

But the output price effect on household utility is positive since $\partial \tilde{U}/\partial p = U_I \tilde{Q} > 0$.

As for the effect of changes in off-farm wage on total household income, we have

$$\frac{\partial \tilde{I}}{\partial w_o} = \frac{\partial \tilde{y}_f}{\partial w_o} + \bar{M} = pG_F \frac{\partial \tilde{F}}{\partial w_o} + \bar{M}.$$

Because $\partial \tilde{F}/\partial w_o$ is negative (see Eq. (28a)), the sign of $\partial \tilde{I}/\partial w_o$ is indeterminate. The sufficient condition under which $\partial \tilde{I}/\partial w_o$ is positive is: $\bar{M} > -pG_F\left(\partial \tilde{F}/\partial w_o\right)$. But an increase in w_o unambiguously increases household welfare since $\partial \tilde{U}/\partial w_o = U_I \tilde{M} > 0$.

With respect to the effects of a change in hiring-in wage on income and utility, we have

$$\frac{\partial \tilde{I}}{\partial w_h} = \frac{\partial \tilde{y}_f}{\partial w_h} = pG_F \frac{\partial \tilde{F}}{\partial w_h} - \tilde{H}.$$

If family and hired labor are complements, it is possible for $\partial \tilde{F}/\partial w_h$ to be negative in sign (see Eq. (29a)) so that total household income decreases with hiring-in wage. But if family and hired labor are substitutes such that $\partial \tilde{F}/\partial w_h$ is positive, total household income may not increase with hiring-in wage unless the following sufficient condition holds: $pG_F\left(\partial \tilde{F}/\partial w_h\right) > \tilde{H}$. But an increase in w_h always lowers utility since $\partial \tilde{U}/\partial w_h = -U_I \tilde{H} < 0$.

Given that $\partial \tilde{F}/\partial Z < 0$ (see Eq. (26b)), the effect of a change in non-labor income on total household income is indeterminate as illustrated by the following derivative:

$$\frac{\partial \tilde{I}}{\partial Z} = \frac{\partial \tilde{y}_f}{\partial Z} + 1 = pG_F \frac{\partial \tilde{F}}{\partial Z} + 1.$$

The sufficient condition under which total household income increases with non-labor income is: $1 > -pG_F\left(\partial \tilde{F}/\partial Z\right)$. An increase in non-labor income increases welfare since $\partial \tilde{U}/\partial Z = U_I > 0$.

Finally, we examine how changes in $\bar{M}$ affect household income. We have

$$\frac{\partial \tilde{I}}{\partial \bar{M}} = \frac{\partial \tilde{y}_f}{\partial \bar{M}} + w_o = pG_F \frac{\partial \tilde{F}}{\partial \bar{M}} + w_o.$$

Other things being equal, an exogenous increase in $\bar{M}$ raises off-farm labor earnings. However, the increase in $\bar{M}$ *lowers* $\tilde{F}$ (see Eq. (30a)), which causes farm production and hence on-farm income to fall.[18] If the increase in off-farm labor earnings more than offsets the decrease in on-farm income, total household income increases. That is, $\partial \tilde{I}/\partial \bar{M} > 0$ if $w_o > -pG_F\left(\partial \tilde{F}/\partial \bar{M}\right)$.[19] It is straightforward to show that $\partial \tilde{U}/\partial \bar{M} = U_I w_o > 0$. We thus have

Proposition 9. *An exogenous increase in off-farm work time, $\bar{M}$, increases total household income when the off-farm wage, w_o, is higher than the decrease in on-farm income resulting from a reallocation of family labor from on-farm work to off-farm employment, $-pG_F\left(\partial \tilde{F}/\partial \bar{M}\right)$. However, the increase in $\bar{M}$ increases household utility.*

Using the 2000 General French Census of Agriculture, Benjamin and Kimhi (2006) examined labor decisions for farm work, off-farm work, and hired farm labor. They found that farm family composition

played an important role in affecting farm women's labor supply decisions and that off-farm labor was negatively related to farm size. Moreover, they found that hired labor was positively associated with farm size, specialization, and status as a partnership. This implies that factors outside the farm sector (such as immigration policy) might indirectly affect the structural change in French farms. The authors also found that farm operators and farm spouses were substitutes and that hired labor is substitute to both male and female farm labor. In a recent contribution, Lien et al. (2010) studied the factors that influence the farm households' off-farm working decision, and how off-farm work influences farm production. They collected panel data set from Norwegian grain farms during 1991 to 2005. Their results showed that age, marital status, number of children, farming region, and farm output influenced off-farm work decisions. However, they did not find sufficient evidence to proof that off-farm work had negative impacts on farm production and farm income.

4. Concluding remarks

In this paper, we examine the relationship between farm production, income, and utility of a farm household in an input-heterogeneity model where on-farm family and hired labor, off-farm labor supply, and leisure are jointly and uniquely determined. Paying attention to interactions between on-farm work and off-farm employment, we analyze how the household adjusts its decisions on labor supply and production in response to changes in external economic conditions. We compare differences in household decisions for the two alternative settings with and without constraints on off-farm labor employment opportunities. Our analysis extends the income-leisure model of Benjamin (1992), and complements the theoretical models by Strauss (1986), Lopez (1984, 1986), Huffman (1980, 1991), and Taylor and Adelman (2003).

In the analysis, we find that the imperfect substitutability of family and hired labor is not critical to a separation between household production and consumption. This finding suggests that empirical studies showing that family and hired labor are imperfect substitutes are insufficient to undermine the separation proposition. We find that the critical factors are constraints on off-farm employment opportunities. We also point out that, regardless of a separation, a farm household's decisions on on-farm family and hired labor are affected by changes in off-farm wages. So will the household's off-farm labor supply be affected by changes in hiring-in wages and the competitive prices of agricultural products. We show how interactions between on-farm work and off-farm employment affect on-farm income and off-farm labor earnings.

The simple models of a farm household have policy implications. First, a policy change that results in a decrease in agricultural price (e.g., due to the removal of a price support program or an agricultural trade liberalization policy) unambiguously lowers household utility. A farm household may respond to the policy change by increasing its participation in local off-farm labor markets in order to increase off-farm labor earnings. A better understanding of how farm households allocate their time between farming and off-farm jobs in reaction to changes in economic conditions may be crucial for designing successful farm policies that improve farm income or reduce income variability of farm families. Second, for the case in which off-farm employment is flexible, increasing direct income payments unambiguously lowers off-farm labor supply and hence reduces off-farm labor earnings. Third, the argument that reducing direct income payments will not affect farm production is valid when off-farm employment opportunities are available to farm households without constraints. However, this argument does not hold when off-farm job opportunities are limited. The reason is that farm production and direct income payments will no longer be independent. In this case, production and on-farm income may be affected negatively when direct income payments are reduced or eliminated.

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[18] Low (1981) found for the case of southern Africa that increases in rural non-farm employment opportunities in some communities resulted in a decrease in agricultural production and income. Further increases in non-farm employment are likely to increase total household income but may instead lower farm production and on-farm income.

[19] Schultz (1990a) showed that earnings from off-farm employment play a prominent role in reducing income variability of agricultural households. Mishra and Goodwin (1997, 2002) further documented a positive relationship between off-farm employment and farm income variability.

The limitations of this paper and hence possible extensions should also be mentioned. First, the paper does not take into account elements of imperfect information and the farm household's attitudes toward risk under uncertainty. It is likely that the production and consumption decisions become non-separable (Mishra and Goodwin, 1997; Benjamin and Kimhi, 2006). Second, the analysis focuses on time allocation from a household's perspective without addressing issues on gender division of farm labor.[20] Third, we anticipate that imperfect labor markets would alter the separability nature of the household decisions, similar to the case with off-farm employment constraints. It might also be worthwhile to take into account minimum wage regulations in the off-farm labor markets when investigating how the public policies would affect the time allocation decision of a farm household.[21]

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[20] See the interesting analysis contribution Udry (1996).

[21] Compliance and noncompliance behavior of non-farm producers subject to the minimum wage laws can also be considered when analyzing the labor supply decisions of farm households to non-farm work. For studies on the behavior of complying and noncomplying minimum-wage firms, see, e.g., Chang and Ehrlich (1985) and Chang (1992), Yaniv (2001, 2004), and Chang and Walia (2007). See also Basu et al. (1999) for an interesting analysis of household labor supply and minimum wage legislation.