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The impact of agricultural and household technologies on women: a conceptual and quantitative analysis in Burkina Faso

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Abstract

Agricultural technologies (new cultivars, inorganic fertilizers, soil- and water-conservation techniques) in Sub-Saharan Africa have been primarily introduced to male farmers by male-dominated extension services on the family plots. These yield-increasing, input-intensive technologies increase the demand for farm labor. So, not only do men obtain most of the direct benefits from the introduction of technology but this labor-intensive technology also increases the demands on women's time for additional labor. This raises the question: Are the combined effects of agricultural technologies beneficial or detrimental to women? We first develop a labor-market model that examines the impact of agricultural and household technologies on labor allocation and income determination within the household. We then discuss the important issue of how household labor-allocation decisions and division of income are made within the family in Sub-Saharan Africa. We use a programming model to estimate the effects of these technologies on household incomes and the income of women. The results indicate that the impact of agricultural technologies depends on the type of decision-making prevailing in the household. In contrast, household technologies increase the welfare of women regardless of the type of decision-making. However, with bargaining behavior, agricultural technologies do benefit women and there is some empirical support for this type of household behavior in Sub-Saharan African households.

Keywords: Agricultural and household technologies; Bargaining; Household decision-making

1. Introduction

One critical policy to foster economic growth in Africa is to shift from traditional, resource-based agriculture to input-intensive, science-based agriculture. Presently, technological change is considered to be the main instrument for growth in African agriculture. As population pressure increases, traditional fallow schemes break down and soil fertility is mined unless higher input levels are utilized. Intensive agricultural technologies with higher purchased input levels and increased labor requirements have been introduced in many regions of Sub-Saharan Africa (Sanders et al., 1996). However, this has raised an

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important question in the development literature: Can technological change make women worse off in Sub-Saharan African agriculture despite increasing household incomes?

We evaluate the impact of agricultural technologies on farm incomes and the incomes of women, using the theory of household decision-making. The literature on households identifies three decision-making systems: exploitation, altruism, and bargaining. In addition to agricultural technologies, a series of new household technologies have also been introduced in this region. We treat these technologies as labor-saving devices and estimate the impact of these technologies and of agricultural technologies on farm and female incomes for the three types of household decision-making.

We first describe the region and the farming system and then develop a labor-market model to examine the effects of new technologies on the incomes and labor allocations of household members. We use a programming model to evaluate the potential impact of technologies on farm incomes and to estimate the potential returns to women from technological change. Some policy inferences are then drawn about family decision-making and the introduction and adoption of technologies.

2. The region and land use

Since the elimination of river blindness in the early 1970s, the Solenzo region (Fig. 1), located in southwest Burkina Faso, has experienced rapid and sustained agricultural growth (McMillan et al., 1998). Solenzo is situated on the border of the Sudano-Guinean region, the high-rainfall zone of Burkina Faso. The French concentrated their research, extension, and development work in this region, focusing especially on cotton. Technological change and resulting yield gains have been rapid in cotton and, during the last 15 years, in maize (Fig. 2). As a result, farm incomes have increased. But what about the distribution of income within the household?

Fig. 1. Agroecological zone of Solenzo, the study site. Note: Solenzo lies just outside the high-rainfall, cotton/maize region; but with the fertile soils of the alluvial zone, cotton is easily extended here. Shown is rainfall at 90% probability. Source: Adapted from Sanders et al., 1996, p. 73.

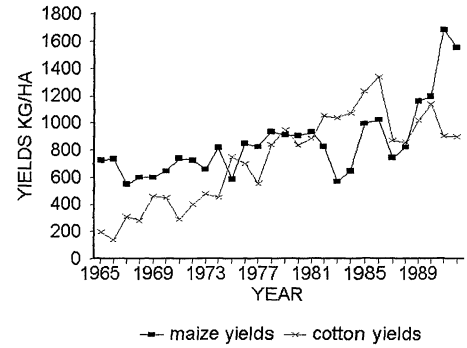

Fig. 2. Maize and cotton yields in Burkina Faso, 1965–1992. Source: Adapted from Sanders et al., 1996, pp. 55, 59.

Most land in Burkina Faso is not privately owned by families or individuals but is allotted to the household head by the village chief/head or land chief. The terms, family and household are used here to represent the extended family that lives and farms together under a singular head of the household. Only 4% of rural households in Burkina are female-headed, which is very small relative to East African countries (Saito and Spurling, 1995, p. 15); hence we do not concern ourselves with them in this analysis. However, in other regions female-headed households are on the rise because of increasing male out-migration to urban areas (Saito and Spurling, 1995).

Within the household no individual family member has the right to alienate (sell) this land, which is the family property of the patrilineage (a system where inheritance goes through the father's side). The farming system that is prevalent can be divided into collectively operated family plots, also sometimes referred to as communal plots and individually operated private plots.

2.1. Family plot

The family plot is the responsibility of the household head and is regarded as the primary enterprise cultivated for the benefit of the extended family. These family plots are generally the higher-quality land located near the household compound or the village site. The household head controls the output from the family plot; he is expected to provide for the basic household consumption of food from this plot. The primary crops produced on the family plots are grains (such as sorghum, millet, and maize) for basic food needs and commercial cash crops (such as cotton and peanuts) (Savadogo, 1990). There is ethnic variability, but generally on the family plot both men and women do the weeding and harvesting and the men are responsible for preparing the fields (Buvinic and Mehra, 1989, p. 292; Fischer et al., 1992, pp. 76–77).

2.2. Private plot

The private fields are regarded as secondary enterprises and are allocated to the household members by the household head when land is available. The individual members control the output from these plots. If there is a divorce in the family, the land reverts back to the household head. This private land is frequently reallocated between years, giving the household head more authority. Generally, lower-fertility land located farther away from the village is allocated to the private plots. These private plots are small in size, 0.4 ha or less, approximately 4% to 6% of the average farm size. In this region, household members generally plant crops, such as peanuts, cowpeas, and a limited amount of red sorghum and vegetables, on their private plots (Savadogo, 1990). Often the women in this region are required to provide some of the household food, especially the vegetables and the sauces for the cereal meal ('toh'), the ingredients for which they raise on their private plots. These secondary enterprises have more limited access to credit, equipment, and purchased inputs than most primary enterprises. Also, the family plot takes priority with respect to labor allocation. Adults are regularly allowed 1 day per week to work on their own plots. On other days, they can work on their private plots only after they have finished their work on the family plot (Saunders, 1980, pp. 6–7; Lilja et al., 1996).

3. Production structure and the introduction of agricultural technologies

Adult female family members allocate their labor resources among four sectors: family plots, private plots, household chores, and off-farm employment. One of the principal activities of women is household chores, which tend to be extremely labor-intensive. Women are often aided by their children with these chores but few labor-saving innovations are utilized. Besides caring for children, the women are responsible for fetching water, gathering firewood, processing and cooking food, and other housekeeping activities.

Besides household chores, the women divide their time between agricultural work on the family and private plots. Women are also often involved in off-farm work, such as beer-brewing and sale, other food processing and marketing, handicrafts, traditional activities such as gathering shea butter ('karite'), and working in the service sector. Some women also work in collectives or workgroups on other farms and in off-farm activities. In a cotton region such as Solenzo this activity is expected to grow rapidly (for details in the same agroecological region in Mali see Lilja, 1996).

To simplify the exposition we build up to the four sectors beginning with the choice between the communal and private fields assuming household labor is done with a fixed amount of time input as the wives are customarily required to do specific household chores. These two sectors, the family plots and the private plots, produce crops utilizing three factors of production: land, labor, and capital.

Households usually mobilize farm labor from within the family. There is growing evidence that an external rural labor market exists in this region and is rapidly expanding particularly for the production of cotton (Savadogo, 1990; Bryson et al., 1992; Saito et al., 1994; Lilja et al., 1996). Nevertheless, household labor is still the predominant form of farm labor and the only source of labor considered in modeling the representative farm household in the paper. However, the external labor market is expected to become an important factor in raising the opportunity cost of the time of women and we will return to it in our conceptual presentation of the labor market for women. It is a very simple extension of the modeling to allow the purchase or sale of labor.

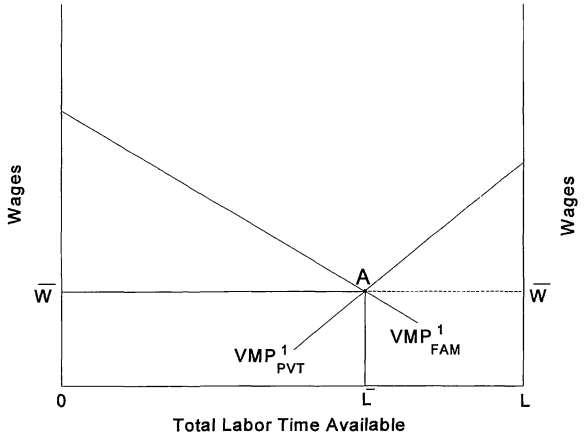

Fig. 3. Allocation of labor in traditional agriculture. Source: Sanders et al., 1996, p. 171.

In 1989 approximately 31% of the households utilized animal traction (Savadogo, 1990). The use of animal traction is on a rise, particularly in response to seasonal labor constraints, so the technologies considered here include both manual traction and animal traction.

3.1. Traditional agriculture

The base case of allocating labor in traditional agriculture with no inorganic fertilizers or other purchased inputs (Fig. 3) can be described as follows:

- OL is the total labor time available to a representative household member (in our case, a female) for allocation between the two sectors.
- VMP^1_{FAM} is the value of the marginal product of labor on the family plot.
- VMP^1_{PVT} is the value of the marginal product of labor on the private plot.
- The intersection of the two curves gives the existing implicit wage rate in the economy and the labor allocation between the two sectors. In the traditional family farm in this region, the household heads do not pay regular wages to their family members. However, they do compensate them in cash or grain during the crop year and at the end of the farming season. The wage rate used in this analysis is an implicit measure of their compensation in both cash, grain and presents.
- $\bar{W}$ is the implicit wage rate, OL is the amount of labor employed on the family plot, and $\bar{L}L$ is the amount of labor employed on the private plots.

In the traditional agricultural system with manual traction, there has been a long-term adjustment of factors of production with respect to information and allocation (Schultz, 1964, pp. 36–52). The ability of the household head to acquire more wives, or to keep the wives he has, is related to the economic support he can provide. Hence, there is an incentive pushing him towards providing for the basic economic needs of the family members. Here we assume this basic economic support is equivalent to the competitive equilibrium of paying household members the marginal value product of their labor services in grain, money, and gifts. This is denoted by the wage rate $\bar{W}$ which represents the marginal productivity of labor in the traditional agricultural system. The long-run competition for acquiring future wives, as well as the desire of the household head for prestige in the community, pushes towards a level of support that approximates the wage rate determined by the neoclassical, perfectly competitive labor market.

Animal traction raises labor productivity and is usually associated with the introduction of other yield increasing technologies (Sanders et al., 1996, pp. 32–36). Animal traction farms are associated with comparatively wealthier household and more wives, as the household head can afford to pay a higher bride price and support more wives. However, to acquire more wives the household head must provide the wives with higher compensation/care as these wives are typically younger, may come from a wealthy family background and may be physically more beautiful. Thus, it appears that there is a differentiated market for wives for the two types of farming households.

3.2. New agricultural technologies

In the past two decades, various new agricultural technologies have been adopted in this region, especially for cotton and maize. These technologies include new varieties of seeds, inorganic fertilizers, pesticides, manure, crop rotation, water-retention, and soil-erosion-prevention techniques. These new farming methods are labor intensive and increase the productivity of land.

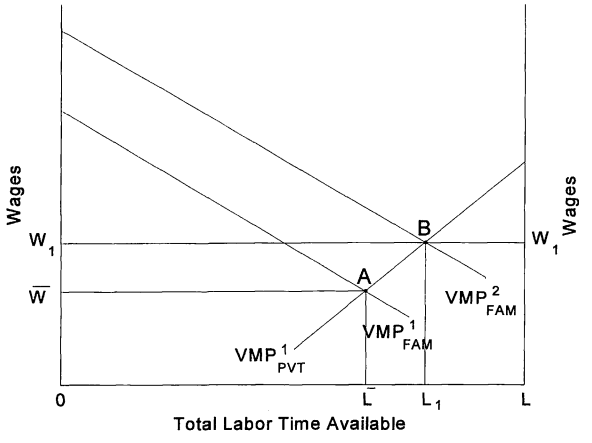

Fig. 4. Allocation of labor with the introduction of agricultural technologies. Source: Sanders et al., 1996, p. 172.

These new agricultural technologies have been principally adopted on family plots controlled by the household head. Principal explanations for higher adoption on the family plots have been the generally higher fertility on the communal plots and the unequal access to technology and complementary inputs on the private plots (Gladwin and McMillan, 1989, pp. 356–357). After the introduction of agricultural technologies, the marginal productivity of labor is expected to increase on the family plots while it may marginally increase on the private plots or remain constant (Fig. 4). With this shift of the long-run equilibrium, how are the increased income streams divided? First, we show the neoclassical response.

- The new equilibrium wage rate is W_1 and the amount of labor employed on the family plots is OL_1 and on the private plot L_1 L. With the introduction of new agricultural technologies: (a) the overall wages have increased, (b) the workers spend more time working on the family plots and reduce their time spent on the private plots, and (c) the returns to labor on the family plot have increased from $\mathbf{O\bar{L}A\bar{W}}$ to OL_1BW_1, whereas the change in returns to labor on the private plot is ambiguous: $L\bar{L}\mathbf{A}\bar{W} \leq$ or $\geq LL_1BW_1$.

4. Decision-making within the household

Next we examine whether this neoclassical view of the returns to labor is adequate by reviewing the literature on family decision making in Sub-Saharan Africa and evaluating how that changes our conceptualization. The implication from standard neoclassical theory is that the household head will share with his wives the increased income streams generated by new technology since their productivity has increased.

However, markets are imperfect and women do not have perfect information about their labor-market alternatives. Nor do women have perfect mobility. Also, social sanctions may exist to enable the household head to demand additional labor from women without necessarily compensating them completely for their increased productivity.

The predominant paradigm in the rural African context is that the household head (male) can exploit other family members in a manner similar to the Marxian concept of exploitation (Folbre, 1986; Gladwin and McMillan, 1989). An alternative theory based on the altruistic or neoclassical approach of Becker (1981) is a benevolent, paternalistic approach where the household head retains decision-making control but maximizes the collective good of the family. A compromise between these two theories is the cooperation/conflict bargaining theory (Sen, 1990; Jones, 1983). This theory asserts that family members will compete for any increased income streams and that their individual share will be determined by their bargaining power within the household. Variations of all three types of family decision-making are expected to be found in Sub-Saharan Africa.

4.1. Exploitation theory

Exploitation theory asserts that the household head can dictate his preferences to the other household members on the division of new income streams and their allocation of labor. Social sanctions are sufficiently strong to pressure other family members to go along with his decisions (Folbre, 1986). With the introduction of agricultural technologies, women work more on the family plots and less on the private plots. In our modeling of exploitation, women then are compensated for the additional time spent on the family plot but at the traditional wage rates, $\bar{W}$ (Fig. 5), Hence, they are unable to capture the increased wage-rate effect from technological change. Nor do their incomes increase. There is a deadweight efficiency loss to society (shaded area in Fig. 5), since women are

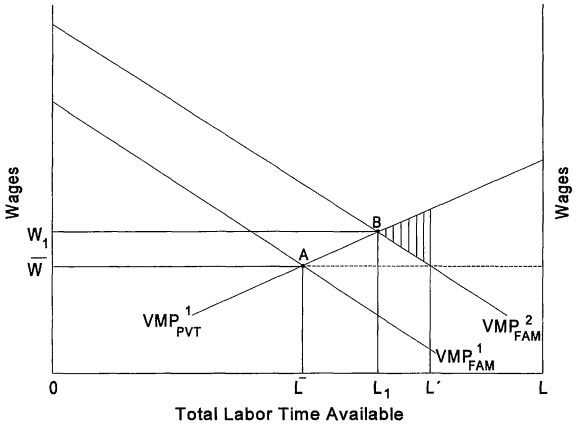

Fig. 5. Allocation of labor with exploitative decision-making and altruism. Source: Sanders et al., 1996, p. 173.

required to allocate too much labor on the family plot (L_1L') and too little labor on their private plots.

A more extreme view is sometimes proposed, i.e., that women are made worse off in terms of payments received with the introduction of technological change. This is possible if compensation to women for increased labor on the family fields is less than the value of their reduced output on the private fields. Then the payments received by women associated with the introduction of technological change are reduced (Gladwin and McMillan, 1989, p. 351).There is some field evidence from Mali that this is the case (Lilja and Sanders, 1998).

4.2. Altruistic theory

According to Becker (1981), household decision-making may be authoritarian but it will be made for the collective good of the family. In reexamining Fig. 5, the neoclassical solution after the introduction of new technology with perfect labor mobility and information is at W_1. We assume this wage rate to represent an approximation to the altruistic behavioral theory. This could even be a conservative view of altruism because the husband still treats the wives as labor rather than as in a cooperative where all are members and the profits are shared. For estimation purposes we are just assuming that the household head would at least pay the women their marginal productivity in spite of the opportunity he has to pay them less arising from labor-market imperfections, such as imperfect mobility of factors and information, and some type of social controls on wives.

Altruism has been challenged for obscuring all conflicts and separate interests within the household (Sen, 1990, p. 125). Is it consistent for economic agents to be motivated by self-interest in the market place and then become altruistic once they cross over the family threshold, especially in families with multiple wives (Folbre, 1986)? Clearly the exploitation school does not believe that the household head would naturally pay women according to their increased productivity resulting from technological change.

4.3. Bargaining theory

Bargaining or conflict/cooperation theory is analogous to decision-making between labor and management within the firm. Each side struggles for larger income shares from higher revenues. Both know that some collaboration is necessary for the survival of the firm or, in this case, the household or the marriage. Each has its threat point or income share below which it withdraws its collaboration: in the case of labor, a strike; in the case of management, a lockout. Applying this to the household, a wife can refuse to work on the family plot the next year or can even return to her parents if she is underpaid at the end of the agricultural season, when most payments take place. Is bargaining behavior consistent with our empirical observations of the African household?

Cash payments for specific labor services, payments to wives for firewood, or lending to women at high interest rates have all been observed within the family in African villages (see the field studies cited in Sanders et al., 1996, p. 162). Field evidence from Cameroon shows that women threaten or actually stop supplying labor if they feel that they are not being compensated adequately (Jones, 1983, p. 1049). A study in Gambia also supports bargaining behavior accompanying the introduction of new rice technologies (von Braun and Webb, 1989). Survey results from Mali in 1995 show that of the households surveyed, 15% of the women would refuse to provide additional labor on the family plots if not adequately compensated (Lilja et al., 1996).

Bargaining theory takes an intermediate position between altruism and the exploitation schools. There is a range between which wages or compensation can

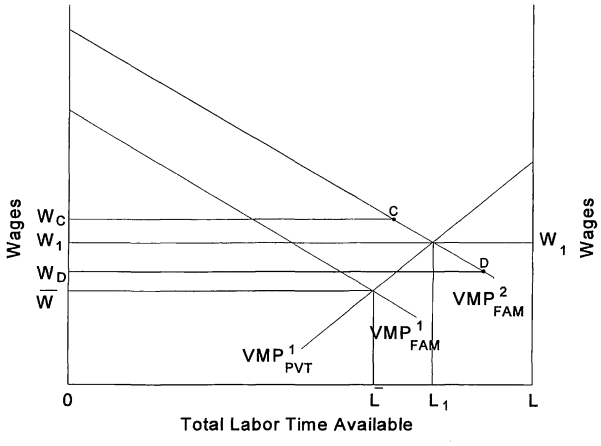

Fig. 6. Labor allocation with bargaining and threat points. Source: Lawrence, 1993, p. 82.

be negotiated. This range is determined by the threat points of the bargaining parties. In the absence of social sanctions and with perfect information and factor mobility, the household head would not be willing to pay more than the marginal value product in agriculture. If he had to pay search and supervision costs of hiring other workers to substitute for the family workers he would further reduce employment (C in Fig. 6). There is also an information problem for him and the other family workers. The expected marginal value product of labor after technological change will depend upon weather and other stochastic factors impacting on production response and output prices. The woman will be prepared to work for the opportunity cost of her time. Her threat point is the wage rate prevalent in the external rural labor market, which is expected to approximate the marginal value product of labor on the farm minus the costs of finding and traveling to any alternative farm employment (D in Fig. 6). The equilibrium wage rate would be between the two threat points, with each party attempting to maximize the gains from bargaining (see Fig. 6).

The bargaining approach appears to be the most consistent with the observed empirical behavior in the African village (Lilja and Sanders, 1998). However, decision-making is expected to differ from one family to another and is anticipated to change over time with economic growth and accompanying cultural and institutional changes.

Are there other ways to increase the incomes of women and/or reduce the demands on their time besides the introduction of agricultural technologies?

5. Introduction of household technologies and off-farm employment activities

Household technologies are often treated as consumer goods in the literature (Agarwal, 1986; World Bank, 1991; Fischer et al., 1992). Little attention has been paid to the value of time saved by women that results from the use of these labor-saving innovations [3]. This additional time can be applied toward other productive, income-generating activities. The potential family income increases from the adoption of household technologies have not generally been perceived in the region. These technologies are viewed as high-status consumer goods. Both males and females think of these household technologies as something that benefit only females by easing their household burden. Moreover, some males expressed the conviction that women have to be kept fully occupied or they will waste time gossiping.

5.1. Household technologies

The household technologies considered here include improved wood-burning stoves, steel-tipped pestles, sori (parboiled sorghum), and wells with water pumps located closer to the village (for details on these technologies see Lawrence, 1993, pp. 26–32). These technologies are included in this study because they have been introduced in this region, can be supported locally, and are cost effective. They also reduce the country's dependence on imported fossil fuel, are sustainable in the long run and help arrest the deforestation and accompanying environmental degradation in this region. With the introduction of household technologies:

- The available labor time increases from OL to OL_0 because of the introduction of labor-saving technologies (Fig. 7).

[3] Household technologies may also exhibit scale effects enabling the woman to extend her activities for the entire family or to handle a larger size family. However, we have not examined this effect and concentrate instead on the labor-saving aspect of these technologies.

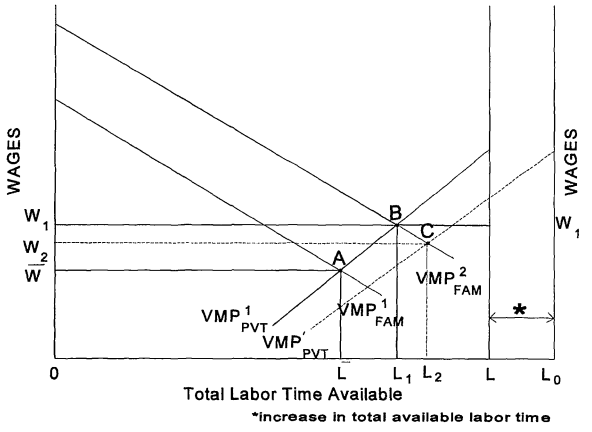

Fig. 7. Labor allocation with the introduction of household technologies. Source: Lawrence, 1993, p. 34.

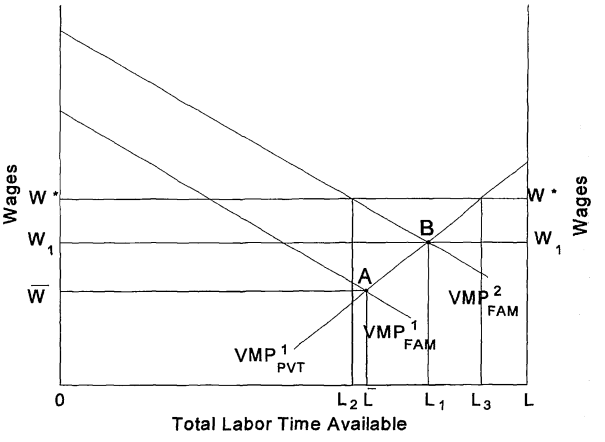

Fig. 8. Labor allocation with the introduction of the off-farm employment sector. Source: Sanders et al., 1996, p. 174.

- The VMP'_{PVT} curve adjusts proportionately because of the introduction of household technologies that causes a shift in the origin.
- The interaction of these two types of technologies results in a wage rate W_2. This wage rate is lower than the wage W_1 (which represents the wage rate associated with the introduction of the agricultural technologies), since increased labor supply lowers the wages. However, the total income may be higher than before, based on the actual slopes of the VMP curves, as the total number of hours available for work increases. Regardless of income, these technologies would still be beneficial to women since they would reduce their time burden.

5.2. *Off-farm employment activities*

Off-farm (agricultural and nonagricultural) activities includes any compensated work outside of providing labor on own-family and private plots. This includes food processing, such as local beer production, preparing meals, and marketing these items. It includes activities such as temporary work in the service sector, working individually or as part of a work group or collective on other farms for wages, or regular off-farm activities. The collective work in gender groups on agricultural tasks in cotton production is expected to be growing rapidly here. The importance of these activities in supplementing women's incomes has been documented (McMillan et al., 1998).

The off-farm employment sector must be more productive than the farm sector so that a wife can pay the transaction costs of finding and getting to alternative employment (Fig. 8). This sector can be characterized as follows:

- The prevailing wage rate in the market is W^*.
- The employment level on both private plots and family plots falls. If the seasonality of labor in agriculture is introduced, the employment of labor on the family and private plots may not fall as much. Allocation of labor could be adjusted so that workers are employed on the farm during the peak farming season and off the farm during the slack season. If off-farm employment does not allow for such adjustments, employment on both family and private plots would fall, as predicted by the model. The new level of labor supply to family plots is OL_2 and the amount of labor supply to private plots is L_3L. The remainder L_2L_3 is supplied to the 'off-farm labor market.'

Availability of the off-farm employment sector raises the opportunity cost facing labor to W^*, increasing the income of women. The provision of off-farm employment opportunities would be expected to elevate the threat point of women, thereby giving them more bargaining power in household decision-making.

6. Methodology

A linear programming model is used to evaluate the impact of new technologies. The objective of the programming model is to maximize net revenue of the representative farm household subject to labor time, land availability, a subsistence constraint, and availability of animal power in the case of animal-traction farms [4]. As new agricultural technologies are introduced, new activities are added to find the optimal combination of crops to be produced, the optimal use of land, and the total farm income. To measure the economic impact of household technologies as productive income-generating technologies, the female-farm-labor-supply constraint is relaxed since the introduction of these technologies reduces female labor time allocated toward household chores. A time reduction of 1.65 h/day was estimated after a detailed study of existing household technologies (Lawrence, 1993, pp 26–32).

The linear programming model used is an extremely detailed model, Model validation was undertaken elsewhere and was found to be a good approximation of actual farm output (Lawrence, 1993, pp 184–186). This model was originally developed by Roth et al. (1986) following extensive fieldwork and has been updated several times to incorporate new technologies and other developments such as the devaluation of currency in 1994. This model is described in detail elsewhere (Roth et al., 1986; Lawrence, 1993; Sanders et al., 1996).

Two separate models are constructed to represent the hand-traction household and the animal-traction household. The former is a smaller household both in terms of availability of land and family labor, whereas the animal-traction household have bigger plots and more family labor available (Savadogo, 1990).

To estimate the returns to technology, three separate runs of the farm-programming model were conducted that included traditional and new activities for both manual-traction and animal-traction farms. The first run was for traditional agriculture prior to the introduction of new technologies. The second incorporated new agricultural technologies. The third reflected the introduction of both agricultural and household technologies.

The implicit wage rates, in each of the six cases, $\bar{W}$, W_1, and W_2 in Fig. 7, were calculated from the programming model of the farm. The wage rate $\bar{W}$ is representative of the long-run competitive equilibrium in traditional agriculture. It is assumed to be 25% higher on animal-traction farms compared to hand-traction farms. If compensation to household members does not increase with the adoption of agricultural technologies, this wage rate $\bar{W}$ becomes the exploitative wage rate after the introduction of new technologies. To evaluate altruistic behavior it is assumed that the household members are compensated according to their marginal value of product and thus are paid $\bar{W}$, W_1, and W_2, the implicit wage rate in each of the three cases. To evaluate bargaining behavior, the Nash bargaining rule is used (Nash, 1953). Nash bargaining implicitly assumes that both bargaining parties can act upon their threat points. (The threat points were defined earlier and illustrated in Fig. 7.) To arrive at a unique solution, the bargaining power of each side must be assessed. The Nash bargaining solution assumes that both parties have equal bargaining power and therefore the distance between the threat points is split [5].

Once these wage rates representing different household behaviors are determined, the returns to women from farm labor on the family plot can be estimated by multiplying by the hours they put in on the communal plots in the linear-programming model. The residual labor time not required by the family plot is then allocated to the private plot and the income for women from this activity is calculated with a separate programming model for the private plot.

7. Results

New agricultural technologies increase farm income on the family plot by 58% (Table 1) for

[4] More sophisticated programming techniques that include risk ·uld be used here. However, our principal concern is to compare long-run comparative static solutions and the linear model was ısidered adequate given the data available.

[5] Another limitation of the Nash bargaining rule is that it ignores the mechanics of the bargaining procedure, i.e., how a solution is actually reached. However, until we have more information about actual bargaining power, the Nash rule of splitting the difference between threat points seems to be reasonable.

Table 1
Annual farm income of a female worker and a farm family before and after the introduction of new technologies incorporating different household behavior in hand-traction farm households (US$)

Household behavior	Traditional agricultural technologies[a]	New agricultural technologies[b]	New agricultural and house hold technologies[c]
Exploitative	50	50	68
Bargaining	50	69	93
Altruistic	50	80	110
Total farm income	354	558	621

[a] Traditional technologies: hand traction, no inorganic fertilizers or other chemical inputs.
[b] Agricultural technologies: moderate inorganic fertilizer, pesticides, and new cultivars of cotton and maize.
[c] Household technologies: include wood-burning stoves, parboiling sorghum, grain processing, wells, and water pumps.
Exchange rate: 541 CFA/US$, World Fact Book, January 1997.
Source: updated from the modeling results of Lawrence, 1993.

hand-traction farm households and 26% (Table 2) for animal-traction farm households. This is a substantial gain and indicates the success the region has been having with introduction of the new agricultural technologies. With the adoption of these technologies, modeling results show that the cultivation on private plots fell by nearly half due to the increased demand for labor on the family plot. This result of declining private plot cultivation is consistent with other field observations (Kumar, 1987, pp. 142–147; Buvinic and Mehra, 1989, p. 298).

If household decision-making is exploitative, women's incomes do not increase with the adoption of agricultural technologies. Nevertheless, even with exploitation, the introduction of household technologies increases the woman's income by 37% for both hand-traction and animal-traction households, assuming that she can allocate the additional time to her private plot (Tables 1 and 2, col. 3). The introduction of the household technologies, by releasing time for women from household chores to farm activities, raises farm incomes on the family plot by an additional 11% in hand-traction households and 12% in animal-traction households. These technologies enable cultivation on both the family plot and the private plots to be expanded. This is an important result and needs to be communicated to the households in this region. If households behave altruistically with the household head paying the value of the marginal product for the work of the family members, the gains from agricultural technologies and both agricultural and household technologies over traditional technology are 60% and 120% for hand-traction farms (Table 1, cols. 2 and 3) and 25% and 63% for animal-traction farms, respectively (Table 2, cols. 2 and 3).

Table 2
Annual farm income of a female worker and a farm family before and after the introduction of new technologies incorporating different household behavior in animal-traction farm households (US$)

Household behavior	Traditional agricultural technologies[a]	New agricultural technologies[b]	New agricultural and household technologies[c]
Exploitative	63	63	86
Bargaining	68	88	114
Altruistic	79	99	129
Total farm income	724	911	1024

[a] Traditional technologies: animal traction, manure, no inorganic fertilizers or other chemical inputs.
[b] Agricultural technologies: moderate inorganic fertilizer, pesticides, and new cultivars of cotton and maize.
[c] Household technologies: include wood-burning stoves, parboiling sorghum, grain processing, wells, and water pumps.
Exchange rate: 541 CFA/US$, World Fact Book, January 1997.
Source: updated from the modeling results of Lawrence, 1993.

If bargaining is the predominant form of household behavior, agricultural technologies increase female incomes by 37% and the joint technology effects increase their incomes by 86% over traditional agriculture in hand-traction households (Table 1, cols. 2 and 3). In animal-traction households with bargaining behavior, agricultural technologies increase female incomes by 29% and the joint technology effects increase their incomes 68% over traditional agriculture (Table 2, cols. 2 and 3).

8. Conclusions

Household decision-making behavior is not static but is expected to evolve with technological change and changing economic opportunity and social norms. In the precarious conditions of subsistence production, household decision-making is probably more authoritarian, with the dominance of the household head as the family sacrifices more democratic decision making to the imperative of making centralized decisions for survival purposes. However, with rapid technological change, as in the Solenzo region, the creation of new income streams is expected to be a catalyst for the evolution of decision-making toward bargaining.

Both agricultural and household technologies raise farm incomes, but agricultural technologies benefit women only if household behavior is characterized by bargaining or by altruism. Household technologies, on the other hand, by releasing female labor time, benefit women directly even in the case of exploitative behavior. Raising the diffusion rate of household technologies is an important goal especially if social customs are fairly resistant to economic growth so that exploitation is common. Marketing household technologies as a productive investment that raises family incomes rather than as consumer goods for women may accelerate their diffusion.

The bargaining approach to decision-making seems to be a more realistic approximation of household behavior as compared with the other two types of household behavior. There is field evidence supporting the existence of household bargaining. However, at any given time, we would expect to find different households exhibiting all three types of decision-making.

From a policy perspective besides the promotion of household technologies, our study suggests the continual dissemination of agricultural technologies onto family fields and the promotion of strategies that strengthen the bargaining position of women, such as expanding their employment and educational opportunities. The evolution in the family decision making towards bargaining is expected to be influenced by the rising opportunity costs of women with increasing off-farm employment opportunities and by their attaining higher educational levels. We have not tested the evolution of household decision-making with economic growth or the factors influencing the bargaining power of women but consider both to be important future areas of investigation.

Female headed households are a fairly insignificant phenomenon in the Sahel but very important in East Africa. Since the main income recipient from technological change is the household head, agricultural technological change would also benefit those households headed by women.

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