Proceedings

Bargaining Models of Rural Households: A Focus on Women (Christina Gladwin, University of Florida, presiding)

The Role of Husbands and Wives in Farm Technology Choice

Lydia Zepeda and Marco Castillo

Until the 1960s, the individual and the household were considered synonymous. With the advent of the "new home economics," unitary household models were developed to look a labor allocation, fertility, and marriage (Becker). Individuals are recognized in these models but are assumed to maximize a single household utility function. During the 1980s household bargaining models, in which individuals have separate utility functions, were developed (Manser and Brown, McElroy and Horney). Bargaining models have been applied to examine demand, marriage, fertility, divorce, and labor supply (Ott). Of particular interest are applications in developing countries where the role of women in agriculture is widely recognized.

However, Rosenfeld found that 44% of all U.S. farms are owned jointly by a husband and wife, 30% of U.S. farm women do farm tasks regularly, and over one-third make joint decisions with their husbands about new farm production practices (Rosenfeld). Despite this, since Griliches's original model in the 1950s, researchers of technology adoption have presumed a single decision maker.

Here we develop alternative models of technology adoption and compare them to the conventional technology adoption model. A unitary household and a cooperative bargaining model are developed and used to examine the role farm women play in the adoption of rotational grazing using survey data from Wisconsin couples. Intensive rotational grazing (IRG) is a relatively new alternative to confinement milk production in Wisconsin. Along with environmental benefits of a constant ground cover and a reduction in the need for farm machinery and energy to run it, IRG also appears to reduce labor requirements (Zepeda et al.).

A Conventional Technology Adoption Model

The general economic framework of the single decision maker adoption model is built on the work of McFadden and of Domencich and McFadden who used Thurstone's random utility formulation. The ith individual is assumed to maximize the expected utility of the present value of profit of the jth technology, where profit, π, is defined as

$$(1) \quad \pi_j = \mathbf{P}_y' f(\mathbf{X}, T_j; \mu) - \mathbf{P}_x' \mathbf{X}$$

with $\mathbf{P}_y$ and $\mathbf{P}_x$ being vectors of output and input prices; $\mathbf{X}$, a vector of inputs that depends upon the jth technology, T, chosen; and $f()$ the production function, which is dependent upon the inputs chosen, the technology, and the given attributes, μ, of the farm and its operator. Solution of the profit-maximization problem yields an indirect profit function $\pi_j(P_y, P_x, \mu)$. Assuming ε is an unobserved component of the profit function, the profit of the jth technology for the

---

Lydia Zepeda is an Economist at the United Nations Food and Agriculture Organization in Rome and an Associate Professor on leave from the University of Wisconsin-Madison, School of Human Ecology. Marco Castillo is a Project Assistant and graduate student in the Department of Agricultural and Applied Economics at the University of Wisconsin-Madison and is on leave from Grupo de Analisis para el Desarollo in Lima.

Funding for this research was provided by the Agriculture Experiment Station project "Rotational Grazing and the Family Farm: Technology, Economics, Sustainability and Gender." The views expressed in this paper are those of the authors and any errors are their sole responsibility.

ith decision maker is denoted by

$$\pi_{ij} = \pi_j(P_{yi}, P_{xi}, \mu_i) + \varepsilon_{ij}.$$

The ith individual chooses the jth technology when the expected utility of the present value of profit of the jth technology exceeds that of alternative technologies $k = 1, \ldots, m - 1$. Thus the probability of the ith individual adopting the jth technology, P_{ij}, can be expressed as

$$P_{ij} = P[\mathrm{E}(\pi_{ij}) \geq \mathrm{E}(\pi_{ik});\ k \neq j,\ k = 1,2, \ldots m]$$
$$= \{\varepsilon_{ik} - \varepsilon_{ij} \leq \mathrm{E}[\pi_j(P_{yi}, P_{xi}, \mu_i)] - \mathrm{E}[\pi_k(P_{yi}, P_{xi}, \mu_i)]\}$$

where P is the probability, and E is a discounted expected utility operator. If the ε_{ij} are independently and identically distributed with a Weibull density function, then McFadden has shown that one can express the probability that the ith individual will choose the jth technology with a standard logit model:

$$(2) \qquad P_{ij} = \frac{\exp \pi_j(P_{yi}, P_{xi}, \mu_i)}{\sum_{k=1}^{m} \exp \pi_k(P_{yi}, P_{xi}, \mu_i)}.$$

A Unitary Household Model of Technology Adoption

Becker and other developers of the "new home economics" proposed unitary household models in which individuals are recognized and allowed different wage rates and marginal productivities but are assumed to have a single household utility function. Though these models have been applied to issues such as household production, fertility, marriage, divorce, and labor supply, they have not been applied to technology adoption.

A unitary household model of technology adoption can be formulated for a two-person household by adding a time constraint and the possibility of off-farm employment to the objective function in equation (1):

$$(3) \qquad \max \mathrm{E}(\pi_j) = \mathrm{E}[P_y' f_j(X, T_j, F_m, F_f; \mu) - P_x'X - \mathrm{B} + P_m'W_m + P_f'W_f]$$
$$\text{s.t. } \Omega_{mj} = W_m + F_m$$
$$\Omega_{fj} = W_f + F_f$$

where F_m is the time spent by the husband on farm production, F_f is the time spent by the wife on farm production, B is the household budget or consumption, P_m is the male's wage, W_m is the time spent in off-farm employment by the husband, P_f is the female's wage, W_f is the time spent by the wife in off-farm employment, Ω_m is the total time available by the husband for farm and off-farm work and Ω_f is the total time available by the wife for farm and off-farm work. The indirect profit function is then $\pi_j(P_y, P_x, \mu, P_f, P_m, B)$ and the probability that the ith individual will adopt the jth technology becomes

$$(4) \qquad P_{ij} = \frac{\exp \pi_j(P_{yi}, P_{xi}, \mu_i, P_{fi}, P_{mi}, B_i)}{\sum_{k=1}^{m} \exp \pi_k(P_{yi}, P_{xi}, \mu_i, P_{fi}, P_{mi}, B_i)}.$$

A Bargaining Model of Technology Adoption

In a bargaining framework, the household is still regarded as the unit of production. However, it is not assumed that individuals are in total agreement about resource or time allocation. Individuals in a household allocate resources within their control to maximize their own utility. Households can be modeled as a noncooperative or a cooperative game.

As a noncooperative game, individuals are unable to make binding contracts because they are not enforceable (Harsanyi). They choose their strategies independently, though not necessarily simultaneously. A strategy that maximizes one person's payoff given the strategy of the other is called a best reply strategy. An equilibrium point is defined when a mutual best reply strategy is reached. Though solutions may not be unique, and may be dynamic, the Cournot-Nash equilibrium, a static noncooperative game with a unique solution, is most frequently used to model household decisions. For simplicity, these models assume noncooperative behavior only for the decision being examined and cooperative behavior otherwise.

Failing a judgment of Solomon in which the couple are permitted to divide their farm operation into two independent enterprises, technology choice among two people requires cooperation, as only a single technology choice is generally possible. Representing technology choice as a cooperative game implies that the couple communicates, an essential condition to make binding contracts (Harsanyi). Cooperative games are Pareto optimal and provide an internal distribution which depends on the bargaining power of the family members (Ott). The outcome in case of a conflict is the conflict point which is an element of the payoff space or feasible set (Roth). It is assumed that there is at least one feasible payoff vector that can be reached through cooperative behavior that is a better outcome for each player than disagreement. Since the player who would lose more in a disagreement is likely to make concessions, disagreement can be used as a threat to bargain with. This threat point or fallback position is often defined as the options outside the game, e.g., separation or divorce (Manser and Brown, McElroy and Horney).

Two possible fallback positions are defined below. The first involves selling the farm and splitting the proceeds. Define the sale price as V, and the proportion received by the female as γ, exogenously determined. Then the fallback earnings of the wife are $\pi_f = P_f W_f + \gamma V$ and those of the husband are $\pi_m = P_m W_m + (1 - \gamma)V$. Defining the indirect expected utility of profit by Φ, the fallback position of each spouse can be defined as $\Phi_i(P_i, V, \gamma)$, where $I = m, f$.

Alternatively, one spouse would keep the farm, transferring some proportion of the profits to the other. For the sake of argument, assume that the husband keeps the farm and the wife receives a transfer related to the earnings of the farm, M. Thus, the fallback earnings of the wife are $\pi_f = P_f W_f + \gamma M(\cdot)$. The fallback position of the husband is the solution to

$$\max E(\pi_m) = E[P_m W_m + (1 - \gamma)M_j(X, T_j, F_m)]$$
$$\text{s.t. } M_j = P_y' f_j(X, T_j, F_m; \mu) - P_x' X$$
$$\Omega_{mj} = W_m + F_m.$$

The solution to the fallback position of the husband can be defined as $\Phi_m(P_y, P_x, \mu, P_m, \gamma)$, and that of the wife as $\Phi_f(P_y, P_x, \mu, P_f, F_m, \gamma)$.

The Nash bargaining model is characterized by the solution to

$$\text{(5)} \quad \max N \{E^f[\pi_j(T_j, X, F_m, F_f, W_m, W_f)] - \Phi_f(\cdot)\} \cdot \{E^f[\pi_j(T_j, X, F_m, F_f, W_m, W_f)] - \Phi_f(\cdot)\}$$
$$\text{s.t. } \pi_j = P_y' f_j(X, T_j, F_m, F_f; \mu) - P_x' X - B + P_m' W_m + P_f' W_f$$
$$\Omega_{mj} = W_m + F_m$$
$$\Omega_{fj} = W_f + F_f$$

The indirect profit function for the case in which the farm is sold is $\pi_j(P_y, P_x, \mu, P_f, P_m, B, V, \gamma)$ and for the case in which some portion of the earnings are transferred is $\pi_j(P_y, P_x, \mu, P_f, P_m, B, \gamma)$. The comparative statics are obviously different in the two cases.

As an alternative formulation, Kooreman and Kapteyn (1990) developed a cooperative bargaining model for labor supply with exogenous bargaining power. Their model can be adapted to the technology adoption decision. The cooperative solution lies on the contract curve defined by max $(1 - \delta)E^m(\pi_j) + \delta E^f(\pi_j)$ subject to the constraints in equation (5), where δ is an exogenous bargaining weight. Thus the probability of the ith farm adopting the jth technology is

$$\text{(6)} \quad P_{ij} = (1 - \delta)P[E^m(\pi_j) > E^m(\pi_k)] + \delta P[E^f(\pi_j) > E^f(\pi_k)]$$
$$= \frac{\exp \pi_j(P_{yi}, P_{xi}, \mu_i, P_{fi}, P_{mi}, B_i, \delta_i)}{\sum_{k=1}^{m} \exp \pi_k(P_{yi}, P_{xi}, \mu_i, P_{fi}, P_{mi}, B_i, \delta_i)}.$$

If $\gamma = \delta$, that is, if the proportion of income transferred equals the bargaining weight, this yields the same reduced-form specification for technology choice as model (5) in which the fallback position involves transfer of a portion of farm income.

Data

A structured telephone survey of Wisconsin dairy farm couples was conducted September 1995 through March 1996. Taylor, Crawford, and Clark counties were selected for their frequency of grazing farms, which was sufficient to allow analysis of the adoption decision. A population list, for the purpose of certifying all producers on the Brucellosis Ring Test, of all 2,140 registered farms in those counties in 1994 was obtained from the State of Wisconsin Department of Agriculture, Trade and Consumer Protection.

The questionnaire was limited to married couples currently operating a dairy farm by themselves. Thus, 1,106 of the farms in the three counties were ineligible (44% because either they were currently not operating a farm or they owned multiple farms and only one response was permitted per person, 18% because they were not married, 24% because an adult living on the farm other than the spouse was involved in major decisions, 14% because an adult living off-farm other than the spouse was involved in major decisions). Of the remaining 1,034 eligible farms, 600 couples completed the survey. This is a response rate of 58%.

Table 1. Description of the Data (n = 365)

Variable	Definition	Mean	Std Dev
T	1 if Grazer, 0 if not	0.288	0.453
College	1 if finished college, 0 if not	0.277	0.448
LnSize	Logarithm of milking herd	3.874	0.477
Motive	1 if profits motivate technology choice, 0 if not	0.375	0.485
Nutrient	1 Soil nutrients are in good condition, 0 if not	0.455	0.499
Meeting	1 meetings are a source of information, 0 if not	0.132	0.338
P_y	Price received per hundredweight milk ($)	12.83	7.95
P_x	Total expenditures/herd size ($1,000/year)	3.234	11.403
P_m	Husband's hourly wage off-farm ($)	1.90	8.12
P_f	Wife's hourly wage off-farm ($)	2.57	4.94
B	Monthly household expenditures ($100/month)	0.958	1.060
δ	1 if husband makes technology decision, 0 if joint	0.488	0.501

Both husbands and wives were questioned separately about decision making, their allocation of time on- and off-farm, their human and financial capital, the family decision-making style, and off-farm wages. The dairy herd and long-term decisions were generally identified by both as being joint decisions. Further details are available in Zepeda et al.

Comparison of Empirical Results of Three Models of Technology Adoption

Equations 2, 4, and 6 represent the conventional, unitary household, and bargaining formulations of a technology adoption model. These models are estimated via logit analysis using the data collected from a Wisconsin survey of dairy farm couples on the adoption of intensive rotational grazing (IRG). Table 1 contains the variable names, definitions, means, and standard deviations of the data. Due to missing values, 365 useable observations are available. However, the proportion of graziers was identical in this reduced sample, avoiding sample selection bias.

The farm and farmer characteristics relevant to the technology adoption decision are education, farm size, motivation for technology choice, environmental conditions, and preferred source of information. Since the level of education of both husband and wife were highly correlated, the husband's level is used. Completion of college was found to be the most relevant in terms of adoption of grazing (College). Age and experience were not included as farmer characteristics, as they are inversely related to education level.

Results of the three models are in table 2. In all three models, education has a significant positive effect on the probability of adopting rotational grazing. Larger farms are also more likely to adopt grazing. Since larger farms tend to be operated by younger farmers it is not surprising that they are more likely to adopt a new technology. They have a longer time horizon in which to recover the costs. Grazing may also be a way of expanding herd size in a less costly manner than conventional dairy farming, since there is a lower capital requirement.

Being guided by a profit motive significantly increases the probability of adopting IRG. Other motives include improving herd health, concern for the environment, spending more time with the family, and machinery requirements. Interestingly, these other factors are thought to motivate IRG adoption, but the overriding factor appears to be money.

Those who believe their soil is in good condition are also more likely to adopt IRG. This may represent somewhat of an endogenous relationship as IRG is thought to improve soil condition. However, as the previous results suggest, improving soil condition is not the primary motive of adopters; profit is.

Among nonadopters, the preferred information source for making a major farm decision was attending meetings. Other sources of information for major decisions included people, print materials, events, and how the farm was farmed in the past. The preference by adopters for information sources other than meetings may reflect the fact that IRG adoption has been farmer led, rather than extension led, in Wisconsin. Prices received or paid do not appear to significantly impact the decision to adopt IRG.

Under the formulation of the unitary household model, the time allocation of husband and wife to farm and off-farm work, as well as the household budget, must be chosen. This leads

Table 2. Comparison of the Results of Conventional, Unitary Household, and Nash Cooperative Bargaining Technology Adoption Models (n = 365)

	Conventional	Household	Bargaining
Constant	−2.496**	−2.754**	−1.558
College	0.659**	0.604**	0.616**
LnSize	0.717**	0.700**	0.553*
Motive	0.631**	0.610**	0.684*
Nutrient	0.398*	0.435*	0.511**
Meeting	−0.638*	−0.624*	−1.011**
P_y	0.016	0.016	0.018
P_x	−0.002	−0.005	−0.006
P_m	–	0.009	0.006
P_f	–	0.029	0.063**
B	–	0.279	0.254
δ	–	–	−1.305**
Log likelihood	−204.96	−202.41	−190.40
Correct predictions	72.6%	72.1%	73.7%

** significant at 5% and * significant at 10%

to inclusion of off-farm wages and the level of the household budget in the unitary household technology adoption model. None of the coefficients of these additional variables are significant. Indeed a likelihood ratio test indicates that their addition does not add significantly to the explanatory power of the adoption model (the chi-squared statistic with three degrees of freedom is 5.09, a p-value of 0.166). Thus the unitary household model in this case does not perform significantly better than the conventional adoption model.

The Nash cooperative bargaining model does do significantly better than both the conventional and the unitary household adoption models, with a chi-squared statistic of 29.1 (four degrees of freedom, p-value of 0.0000) and 24.0 (one degree of freedom, p-value of 0.0000), respectively. Not only is the bargaining weight significant, but female wages also become significant. The higher the female wage, the greater the probability that the farm will adopt IRG. Since the time-use data collected in the survey indicates that IRG farms utilize less labor, particularly less female labor than conventional farms (Zepeda et al.), IRG may represent a strategy that allows farm households to capture the wage potential of farm women. Alternately, IRG may be a response to the lower availability of female labor because they work off-farm.

The sign on the bargaining weight indicates that when the husband makes unilateral decisions about technology, the probability that the farm will adopt IRG is lower. In other words, IRG is more likely to be adopted by those households in which technology choice is a joint decision. Interestingly, joint decisions are more prevalent among older couples (Zepeda et al.), so this result does not reflect the ability of a farm to capture the returns to the technology over a longer time horizon. What it would appear to reflect, given the difference in time allocation between graziers and nongraziers, is that IRG may be part of a joint strategy of specialization and diversification. The lower labor requirements of IRG (Zepeda et al.) are compatible with off-farm employment of wives.

High wages may permit wives to exert more power over farm decisions by strengthening their fallback position. However, since wives are no more favorably disposed toward IRG than husbands, this does not by itself explain why joint decision making is associated with IRG adoption, unless IRG is part of a joint strategy which includes the wife working off-farm.

One could also view the sign of the bargaining weight either as evidence that "two heads are better than one" or as a game of "chicken." In the former, the use of joint decision making may permit greater evaluation of alternative technologies than one person would be able to do. In the latter case, one person may willing to take the risk of adoption if their partner is willing. That is, a unilateral decision maker may be more cautious about technology adoption.

Conclusions and Implications

A unitary household model and a Nash cooperative bargaining model of technology adoption are derived and compared to a conventional model of technology adoption. The three models are estimated using data from Wisconsin dairy farm couples on adoption of intensive rotational grazing (IRG). The results indicate that the unitary household model does no better at explaining adoption of IRG than the conventional model. The bargaining model is significantly better at explaining IRG adoption than both the conventional and the unitary household model.

The results of the bargaining model reveal that IRG adoption may be part of a household strategy to free female labor to work off-farm. In households where technology adoption is a joint decision, IRG is more likely to be adopted. Rather than diminishing their influence on farm decisions by working off-farm, high-wage employed women appear to have a stronger influence on farm decisions.

One implication of this work is that farm technology decisions cannot be viewed as an isolated decision but as part of an overall household strategy. The greatest impediment to doing this is the lack of data on farm women. One result of the conventional formulation of a technology adoption model is that data is routinely collected from only one person. Thus the role a technology choice may play in an overall household strategy cannot be identified.

A natural extension of this work is to look at intergenerational issues. Most farms are family businesses. The role of children and parents in technology choice and other farm decisions merits exploration. A further issue to explore is the endogeneity of the bargaining weight.

References

Becker, G.S. *A Treatise on the Family*. Cambridge MA: Harvard University Press, 1981.

Griliches, Z. "Hybrid Corn: An Exploration in the Economics of Technological Change." *Econometrica* 25(1957):501–22.

Domencich, T.A., and D. McFadden. *Urban Travel Demand: A Behavioral Analysis*. Amsterdam: North Holland, 1975.

Harsanyi, J.C. *Rational Behavior and Bargaining Equilibrium in Games and Social Situations*. Cambridge MA: Cambridge University Press, 1977.

Kooreman, P., and A. Kapteyn. "On the Empirical Implementation of Some Game Theoretic Models of Household Labor Supply." *J Human Resour.* 25(1990):584–98.

Manser, M., and M. Brown. "Marriage and Household Decision Making: A Bargaining Analysis." *Int. Econ. Rev.* 21(1980):31–34.

McElroy, M., and M.J. Horney. "Nash-Bargained Household Decisions: Toward a Generalization of the Theory of Demand." *Int. Econ. Rev.* 22(1981):333–49.

McFadden, D. "The Measurement of Urban Travel Demand" *J. Public Econ.* 3(1974):303–28.

Ott, N. *Intrafamily Bargaining and Household Decisions*. Berlin: Springer-Verlag, 1992.

Rosenfeld, R.A. *Farm Women: Work, Farm, and Family in the United States*. Chapel Hill: The University of North Carolina Press, 1985.

Roth, A.E. *Axiomatic Models of Bargaining*. Berlin: Springer-Verlag, 1979.

Thurstone, L. "A Law of Comparative Judgement." *Psych. Rev.* 34(1927):273–86.

Zepeda, L., M. Castillo, K. McSweeney, and D. Undersander. "The Role of Wisconsin Women in Dairy Farm Decision Making: A Comparison of Survey Data on Graziers and Non-Graziers." Department of Consumer Science, University of Wisconsin, 1996.