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In Defense of Fence to Fence: Can the Backward Bending Supply Curve Exist?

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Politicians dealing with the "farm problem" sometimes lament that output increases when prices go up and when prices go down. This article presents three possible theoretical explanations. In the first, farmers deplete soil (overfarm) when prices are low and imperfect capital markets prevent borrowing. In the second, farmers in financial stress (low prices) allocate more family labor to farming to meet debt-repayment constraints. In the third, wealth held in farmland tends to decline as prices decline. With decreasing absolute risk aversion, this increases risk aversion which, in extreme cases, causes negative supply response.

Key words: debt constraints, family labor, risk, soil depletion, supply response.

Introduction

A common complaint among old economists and old politicians is that farmers increase output when prices go up and farmers increase output when prices go down. While the former has attracted a great deal of economic research and raised the status of agricultural economists, the latter has irritated politicians and confounded economists. Both have been led to believe that quantity supplied increases with price and any other pattern of behavior should be passed off as bad data or poor analysis. After all, standard economic theory teaches no alternative to the "law of supply."

While economists rarely make statements in print that admit violations of the law of supply, Galbraith and Black took this view for granted in trying to explain the high production levels that occurred during the Great Depression. Politicians are more explicit. For example, Senator Tom Harkin has stated that "when price falls, the farmer goes out and plants more." On another occasion, this senator further claimed that the negative supply response for declining prices is greater than the positive supply response for rising prices. Paarlberg has recently underscored the prevalence of these views among farmers and policy makers and their inconsistency with conventional economic wisdom in a *Choices* article on the "myth" of the "backward bending supply curve."

This article discusses possible theoretical explanations for this phenomenon which is casually referenced by politicians but likely to be uncomfortably resisted by young economists in search of publishability. After all, traditional practice leads any aspiring economist who estimates a negative supply elasticity to quickly discard it. In spite of strong prejudices against such notions, empirical evidence occasionally finds its way into print. For example, Saez and Shumway found negative supply elasticities in the U.S. for four of ten regions for livestock, three of ten regions for feed grains, two of eight regions for food grains, two of seven regions for cotton, two of seven regions for oil crops, six of ten regions for vegetables, and three of three regions for tobacco. Negative supply elasticities have been found for dairy in Canada and wheat in Nigeria (Frohberg and Kromer). A U.S. Department of Agriculture (USDA) study found a negative supply elasticity for rice

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in Tanzania. (As this research shows, negative supply elasticities may be particularly plausible for developing countries and poor regions.)

This article uses three separate areas of economic theory independently to show plausibility of the behavior whereby farmers increase output when prices move above normal (as usual) but also when prices move below normal, i.e., cases where both unusually high and unusually low prices may reasonably motivate planting fencerow-to-fencerow. These short-run circumstances may generate isolated data sets where negative supply elasticities are fully plausible. This article identifies sets of circumstances where negative supply elasticities are consistent with theory so that the plausibility of such findings can be evaluated. In each case, very simple models are used to illustrate the principles involved. Obvious and more realistic generalizations are foregone for purposes of brevity.

The next section draws on the theory of intertemporal decision making to show that farmers may be induced to sacrifice future productive capacity in order to increase immediate income in periods of low prices. Similarly, they may be induced to sacrifice future productive capacity in order to make a "quick buck" in periods of excessively high prices.

The succeeding section draws on the theory of safety principles (Freund; Katoaka; Roy) to examine potential farmer behavior during periods of financial stress. While safety principles have not been popular in the literature, they are more plausible under modern generalizations of utility theory (Machina; Quiggin). If the first priority is to meet some debt repayment requirement, a farmer will be willing to allocate more time to labor, thus increasing output above normal when prices fall to very low levels and bankruptcy threatens. On the other hand, when debt repayment constraints are not binding, labor input may increase with output prices following the usual neoclassical framework.

A third section draws on the theory of decision making under risk aversion (Arrow) where wealth is affected by changes in land prices. As agricultural output price levels decline, land prices decline and, as a result, wealth of farmers declines. With decreasing absolute risk aversion, this causes an increase in risk aversion in which case the risk avoidance effect can temporarily overcome the profit motive, resulting in negative supply response.

Farm Now—Pay Later

Consider first a two-period model reflecting the productive impact of soil regenerative activities such as summer fallowing or crop rotation.[1] In some of the more arid northern wheat states, fallowing has accounted for about a third of the use of cropland historically. Even in some of the most productive farming states, secondary crops account for a major share of farmland use because of crop rotation. These practices are pursued to maintain or enhance future productivity of farmland. However, they also give a farmer flexibility to increase output in the short run by reducing fallow or rotation activity with the expense of reducing future output.

To demonstrate this behavior simply, let the farmer's intertemporal utility function be given by $U(\pi_1, \pi_2)$, where π_1 is profit in period 1 and π_2 is profit in period 2. Suppose profit in each period t follows a restricted profit function with profit depending on output price P_t and input prices (suppressed for simplicity) given acreage A_t available for production. Standard assumptions include $\partial\pi_i/\partial P_i > 0$ and $\partial\pi_i/\partial A_i > 0$. In addition, suppose that using more acreage for production in the first period detracts from productivity in the second period so that $\partial\pi_2/\partial A_1 < 0$. For example, acreage can be increased in the present period by foregoing fallowing which then decreases future productivity.

The joint two-period utility maximization problem is

$$\max_{A_1, A_2} U(\pi_1, \pi_1),$$

for which first-order conditions are

$$\text{(1)} \qquad \frac{\partial U}{\partial A_1} = \frac{\partial U}{\partial \pi_1}\frac{\partial \pi_1}{\partial A_1} + \frac{\partial U}{\partial \pi_2}\frac{\partial \pi_2}{\partial A_1} = 0,$$

$$\frac{\partial U}{\partial A_2} = \frac{\partial U}{\partial \pi_2}\frac{\partial \pi_2}{\partial A_2} = 0.$$

The first condition states that the optimal acreage in period 1 is determined so that the marginal utility of acreage (the product of marginal utility of profit and marginal profit of land) is equal to the marginal reduction in period 2 utility because of land use in period 1. The second condition states that optimal acreage in period 2 is determined so that the marginal utility of land use is zero.

Comparative static analysis of this set of first-order conditions yields[2]

$$\text{(2)} \qquad \frac{dA_1}{dP_1} = -\frac{1}{|H|}\frac{\partial^2 U}{\partial A_2^2}\left[\frac{\partial U}{\partial \pi_1}\frac{\partial^2 \pi_1}{\partial A_1 \partial P_1} + \frac{\partial^2 U}{\partial \pi_1^2}\frac{\partial \pi_1}{\partial P_1}\frac{\partial \pi_1}{\partial A_1} + \frac{\partial^2 U}{\partial \pi_1 \partial \pi_2}\frac{\partial \pi_1}{\partial P_1}\frac{\partial \pi_2}{\partial A_1}\right],$$

where H is a matrix of second-order derivatives of U with respect to A_1 and A_2. Note that $|H| > 0$ and $\partial^2 U/\partial A_i^2 < 0$ when second-order conditions hold. Thus, the sign of (2) is the sign of the last term in brackets.

The expression in brackets suggests that a change in output price in the first period has three effects on first-period acreage—one positive, one negative, and one ambiguous. An increase in P_1 tends to increase the value of marginal product of land $(\partial^2\pi/\partial A_1 \partial P_1 \geq 0)$ and that increases acreage. This is the familiar effect of output price under profit maximization in static producer choice problems. The other two effects emanate from the intertemporal utility maximization criterion. An increase in P_1 tends to increase profits and thus reduce the marginal utility of profits in period 1 (because $\partial^2 U/\partial \pi_1^2 < 0$); therefore, the second effect is negative. For the third term, the increase in first-period profit will increase (decrease) the marginal utility of profit in period 2 if $\partial^2 U/\partial \pi_1 \partial \pi_2 > (<)\ 0$.

Because of the ambiguity in equation (2), some special cases can serve to illustrate the validity of the negative supply response potential. One interesting case of backward bending supply occurs when utility is additively separable over time but marginal utility declines rapidly. Additive separability of utility implies that $\partial^2 U/\partial \pi_1 \partial \pi_2 = 0$, in which case the term in brackets in (2) can be rewritten as

$$\text{(3)} \qquad \frac{\partial U}{\partial \pi_1}\left[\frac{\partial^2 \pi_1}{\partial A_1 \partial P_1} + \frac{\partial^2 U/\partial \pi_1^2}{\partial U/\partial \pi_1}\frac{\partial \pi_1}{\partial P_1}\frac{\partial \pi_1}{\partial A_1}\right].$$

Now suppose that constant returns to scale applies, in which case $\partial \pi_1/\partial A_1 = \pi_1/A_1$ and, by Hotelling's lemma, $\partial \pi_1/\partial P_1 = A_1 Y_1$, where Y_1 is yield per acre. Thus, (3) can be expressed as

$$\text{(4)} \qquad \frac{\partial U}{\partial \pi_1} Y_1 (1 - R_r),$$

where $R_r = -[(\partial^2 U/\partial \pi_1^2)/(\partial U/\partial \pi_1)]\pi_1$ is the Arrow–Pratt measure of relative risk aversion for the first period. Note that relative risk aversion is used here for a riskless problem merely to assess plausible curvature of the utility function as in Turnovsky, Shalit, and Schmitz. Arrow has argued that relative risk aversion is around 1 and may plausibly be either somewhat more or less. Clearly from (4), however, curvature associated with relative risk aversion for first-period income greater than 1 generates negative supply response for the first period. Arrow argues that relative risk aversion is increasing, which implies that the condition generating negative supply response for the first period tends to occur for producers with higher first-period income.

For another case illustrating the potential of negative supply response, consider the extreme case of preferences for income stability where profits in the two periods are perfect nonsubstitutes (rectangular indifference curves) implied by $U(\pi_1, \pi_2) = U[\min(\pi_1, \pi_2)]$. (Intertemporal discounting is ignored here assuming all variables are represented in discounted terms.) This case may be appropriate for poor farmers or with chaotic financial markets where credit constraints prevent stabilizing income by borrowing against the future in poor income periods. An internal solution for this problem leads to adjusting acreage use in the first period so that $\pi_1 = \pi_2$, for which comparative static analysis yields

$$\frac{dA_1}{dP_1} = \frac{\partial\pi_1/\partial P_1}{\partial\pi_2/\partial A_1 - \partial\pi_1/\partial A_1}.$$

This expression is unambiguously negative because increasing first-period use of land both adds to first-period output and detracts from second-period output to bring profits in the two periods into balance. Thus, given (*a*) imperfect capital markets that prevent borrowing against future income and (*b*) preferences for intertemporal income stability, farmers will tend to borrow against future productivity by overusing land to increase output when prices and incomes are low.

These cases suggest that land conservation activities can be postponed under prices at either extreme. At high current prices, producers respond normally by increasing current output. On the other hand, if prices fall sufficiently, intertemporal preferences tilt more strongly toward the current period because of diminishing marginal utility. Thus, producers become more willing to borrow against future income by depleting soil fertility and losing the biological benefits of rotation as current price falls too low.

Work Now—Pay Now

Consider next a simple model where a farmer can attempt to avoid pending financial disaster through adjustment of family labor inputs. The development literature has long emphasized the importance of considering explicitly alterations in behavior at or near subsistence levels of income. Models with various safety rules (e.g., safety-first or safety-fixed) have found wide applicability in such problems. Because of the farm debt crisis and the accompanying danger of bankruptcy facing many farmers, such survival considerations are now also of interest in developed agriculture as well. For example, Leathers and Chavas have recently used safety rules to justify government intervention in U.S. agriculture. Robison, Barry, and Burghardt have shown that during periods of financial stress, firms may increase borrowing as a means of forestalling bankruptcy. They characterize this as "go for broke" behavior by highly stressed borrowers. The model here introduces a safety rule in the agricultural household production model to demonstrate similar drastic alteration in behavior in production activity that can take place with financial or subsistence constraints.

To illustrate this behavior simply, consider a farmer with a utility function $U(\pi, T)$, where π is income, and $T = \bar{L} - L$ is leisure time, where $\bar{L}$ is total time and L is work time. Suppose income is represented by $\pi = pq - wx$, where p is output price, $q = f(x, L)$ is a production function defined on input x and family labor L, and w is the price of x. Finally, assume that income must be sufficient for the farmer to meet a financial obligation D (a constrained income problem) or that the farmer acts so as to first meet an income level D sufficient for subsistence needs (a safety-first principle with respect to household consumption). The farmer's problem can be formally stated as

$$\max\{U(\pi, T) \mid \pi \geq D\}.$$

After substitution for π and T, the Lagrangian for this problem is

$$\mathcal{L} = U[pf(x, L) - wx, \bar{L} - L] + \lambda[pf(x, L) - wx - D],$$

which has Kuhn–Tucker conditions

(5) $$(pf_x - w)(U_\pi + \lambda)x = 0,\ x \geq 0,$$

(6) $$[pf_L(U_\pi + \lambda) - U_T]L = 0,\ L \geq 0, \quad \text{and}$$

(7) $$[pf(x, L) - wx - D]\lambda = 0,\ \lambda \geq 0,$$

where subscripts represent derivatives.[3] Assuming $U_\pi > 0$, condition (5) implies that either $x = 0$, or $\pi_x = pf_x - w = 0$. Similarly, the condition in (7) implies that either $\lambda = 0$, in which case the constraint is not binding, or $\lambda > 0$, in which case the constraint is binding. If the constraint is not binding, then one can determine from the unconstrained problem that $dq/dp > 0$ likely holds under normal conditions, although supply may become backward bending at very high prices as the farmer becomes unwilling to work much at high income levels (Becker).

The interesting case is where $x > 0$ and the constraint is binding. In this case comparative static analysis of the two equations, $pf_x - w = 0$ and $pf(x, L) - wx - D = 0$, yields

$$\frac{dL}{dp} = -\frac{f}{pf_L}, \qquad \frac{dx}{dp} = \frac{ff_{xL} - f_x f_L}{pf_L f_{xx}},$$

so that

$$\frac{dq}{dp} = f_x \frac{dx}{dp} + f_L \frac{dL}{dp} = \frac{ff_x f_{xL} - f_x^2 f_L}{pf_L f_{xx}} - \frac{f}{p}.$$

If f is homogeneous of degree one, then the elasticity of substitution is $\sigma = f_x f_L / ff_{xL}$ (Ferguson, p. 96). If $\sigma \leq 1$, then $dx/dp \leq 0$ and $dq/dp \leq -f/p < 0$. Thus, negative supply response occurs under very reasonable conditions. A farmer facing a binding credit constraint will tend to substitute labor for leisure to meet obligations in periods of low price, thus increasing output.

Additional manipulation or simple intuition in this problem shows that if the income constraint becomes binding, it does so below some critical price level p_0 which depends on the input price w. The slope of supply below p_0 is thus negative, while output supply above p_0 follows the usual positive slope except for possible backward bending at high income levels because of the labor–leisure tradeoff (Becker).

These results demonstrate how increased output may be induced by declining prices in a period of credit crisis while increased output is also induced by increases in price above normal levels. For example, suppose prices fall, causing a farmer to fall into a liquidity problem such that credit sources are exhausted and postponing a financial obligation is impossible. Then, if productive uses of labor can be identified, the farmer can try to meet the obligation by working more (or exerting family members more) than otherwise. On the other hand, if prices increase, financial obligations may become less binding so that family labor allocation will be motivated by the usual unconstrained marginal income considerations.

While the analysis here does not treat labor markets explicitly, it can be easily extended to include off-farm labor markets. In such situations, financial distress may lead family members with off-farm work potential to work elsewhere while other family members (children) take over farm labor activities. This de facto extension of the labor supply tends to drive down the rural wage rate, creating a secondary effect of farm output expansion.

Data for considering the applicability of this explanation are extremely limited.[4] However, a recent study of 228 married farm women in Yolo County, California (Thompson, Gwynn, and Sharp) found that women's participation in farming activities tends to increase in times of economic adversity, reflecting "the need for the entire family to use its total resources for survival" (p. 17). These results do not confirm negative supply response but they provide empirical support for the hypothesis that farm families tend to work harder during periods of depressed agricultural prices. Perhaps some of the increased labor is used to substitute for purchased inputs. These observations again suggest that supply response tends to decline and possibly become negative in periods of recession.

Poor Conservatism and Rich Speculation

The third case of this article considers the role of risk aversion in output supply and how it is affected by booms and busts in agricultural markets. Risk has long been established as an important factor affecting farm decision making (Just). Following the theory of risk aversion advanced by Arrow, the degree of risk aversion depends on wealth. In particular, Arrow argued that decreasing absolute risk aversion is more plausible than constant or increasing absolute risk aversion. Also, Pope and Just have shown empirically that constant relative risk aversion is more consistent with agricultural supply response than constant absolute or constant partial relative risk aversion. Of course, constant relative risk aversion implies decreasing absolute risk aversion. Thus, decreasing absolute risk aversion is assumed here, which implies that risk aversion is higher with lower wealth.

Wealth, in turn, depends on average output price levels which are capitalized into land values. Thus, agricultural booms and busts influence risk aversion. In a boom period, profits are high and the role of risk aversion declines as wealth increases, resulting in normal positive response to output prices. In a bust period, land prices decline causing wealth to decline and risk aversion to increase. Just and Zilberman have extended the Sandmo framework to demonstrate that high risk aversion resulting from unusually low wealth can cause negative supply response. This occurs because the tendency to avoid risk may temporarily overcome the desire for profit.

To demonstrate these results in a simple model, assume that output is produced with multiplicative risk so that $x = \bar{x}\epsilon$, where x is actual output, $\bar{x}$ is expected output, and ϵ is a random disturbance, $E(\epsilon) = 1$. Suppose wealth following production is given by

$$W = px - C(\bar{x}) + W_0,$$

where p is output price, $C(\bar{x})$ is a cost function defined on expected output, and W_0 is initial wealth. The farmer maximizes expected utility of wealth, $E[U(W)]$, through choice of expected output, which leads to the first-order condition

$$\frac{\partial EU}{\partial x} = E[U'(p\epsilon - C'] = 0.$$

To examine supply response, note that second-order conditions imply $\partial^2 EU/\partial\bar{x}^2 = E[U''(p\epsilon - C')^2 - U'C''] < 0$, which holds with risk aversion and convex costs, and that comparative static analysis of the first-order condition implies

$$\frac{\partial\bar{x}}{\partial p} = -\frac{E[U''(p\epsilon - C')\bar{x}\epsilon + U'\epsilon]}{\partial^2 EU/\partial\bar{x}^2}.$$

When second-order conditions hold, this expression has the same sign as the numerator, which is inconclusive. The last numerator term, representing the expected profit effect, is positive. The other numerator term has two components. One of the terms, $EU''p\bar{x}\epsilon^2$, is negative and the other, $-EU''C'\bar{x}\epsilon$, is positive. This suggests that supply is not necessarily positively sloped under risk aversion.

A better understanding of conditions that lead to negative supply response is obtained by using a second-order Taylor series approximation of the utility function at expected wealth, $\bar{W}$,

$$U'(W) = U'(\bar{W}) + p(x - \bar{x})U''(\bar{W}).$$

This allows the first-order condition to be approximated by

$$\frac{\partial EU}{\partial\bar{x}} = U'(\bar{W})(p - C') + U''(\bar{W})E[p(x - \bar{x})(p\epsilon - C')] = 0.$$

Dividing by $U'(\bar{W})$, this condition is equivalent to

$$p - C' - \phi p^2\bar{x}\sigma^2 = 0,$$

where $\sigma^2 = V(\epsilon)$ and ϕ is absolute risk aversion at expected wealth,

$$\phi(\bar{W}) = -U'(\bar{W})/U''(\bar{W}).$$

Comparative static analysis of this equation and use of the second-order condition yields

$$\frac{d\bar{x}}{dp} > (<)\ 0 \text{ as } 1 + \phi\bar{W}\sigma^2 S(\eta\delta - 2) > (<)\ 0, \tag{8}$$

where η is the elasticity of risk aversion, $\eta = -(\partial\phi/\partial\bar{W})(\bar{W}/\phi)$; S is the share of expected current revenue in expected wealth, $S = p\bar{x}/\bar{W}$; and δ is the elasticity of expected wealth with respect to price, $\delta = (\partial\bar{W}/\partial p)(p/\bar{W})$.

Equation (8) demonstrates that price has three effects on the slope of supply under uncertainty: a mean effect represented by the 1, a variance effect represented by $-2\phi\bar{W}\sigma^2 S$, and a wealth effect represented by $\eta\delta\phi\bar{W}\sigma^2 S$. The mean effect tends toward positively sloped supply as in the deterministic case. The variance effect, however, tends toward negatively sloped supply because an increase in price increases the variance of profit. The wealth effect reflects the increase in absolute risk aversion as wealth gets smaller.

To determine the overall effect of price on the slope of supply, suppose that current price changes are perceived as short run in nature so that expected wealth is relatively unaffected. Thus, δ is small. Note also that, according to Arrow, relative risk aversion is approximately 1, which implies that $\phi\bar{W}$ is approximately equal to 1, i.e., $\phi \cong 1/\bar{W}$. Finally, note that η approaches zero for near-constant absolute risk aversion. Under these conditions, the term on the right-hand side of (8) approximates $1 - 2\sigma^2 S$. The interesting aspect of this result is that the variance effect tends to override the mean effect when wealth is small (S gets large), while the wealth effect becomes inconsequential in the short run. Thus, the short-run response to a decrease in price is an increase in output if wealth is sufficiently small. And, of course, wealth is small, approaching zero for many farms, in a bust period such as the recent farm debt crisis.

Again, data for examination of this phenomenon are scarce. Very few published studies have investigated how risk aversion varies with wealth. However, Just and Zilberman recently have shown that negative supply response is plausible with low wealth using Roumasset's data on the distribution of returns among crops with levels of risk aversion found empirically by Binswanger.

Conclusions

The analysis of this article has shown that supply may not necessarily have positive slope for individual farmers. Negatively sloped supply may occur in the short run as a result of declining marginal utility of income, a safety-first response to a debt crisis, or a risk averter's response to a critical decline in wealth. While each of these phenomena tend to occur with weak agricultural prices, it is important to recognize that the circumstances which could generate negatively sloped supply depend critically on individual circumstances (curvature of utility, debt-equity levels, and wealth). Thus, with heterogeneous farm populations, negatively sloped supply may be relevant for only certain segments of the farm population. Therefore, detecting negative supply response empirically may be difficult or impossible with aggregate data. Nevertheless, the forces that tend toward negative supply response may have important impacts on aggregate supply response and cause the supply elasticity of agriculture to vary with economic conditions.

For example, at each point in time, the distribution of characteristics among firms results in an associated aggregate supply elasticity. When this distribution places larger segments of the farm population in low income, debt crisis, or low wealth situations, the aggregate supply curve may have lower elasticity. Aggregation of individual firm responses with these considerations suggests three propositions about aggregate agricultural supply. First, the elasticity of aggregate supply tends to increase with increases in prices, wealth, and cash flow (after debt service). Second, the elasticity of aggregate supply tends to decrease with higher interest rates. For example, an increase in interest rates reduces cash flow after debt service, which tends to reduce supply elasticity. Also, because discount rates tend to be tied to interest rates, an increase in interest rates tends to be associated with a decline in the capitalized value of land which is farmers' primary form of holding wealth. Third, the elasticity of supply depends on the dynamics of land price adjustment and the structure of risk preferences. Strengthening land prices raises wealth and causes more elastic supply, while weakening land prices lowers wealth and reduces supply elasticity.

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Notes

[1] See Antle and Howitt, and Johnson and Quance for a general discussion of fertility mining.
[2] Comparative static analysis actually results in an additional term in equation (2) given by

$$\frac{1}{|H|}\frac{\partial^2 U}{\partial A_1 \partial A_2}\frac{\partial^2 U}{\partial \pi_1 \partial \pi_2}\frac{\partial \pi_1}{\partial P_1}\frac{\partial \pi_2}{\partial A_2}.$$

However, this term is zero by first-order conditions. That is, the first-order condition with respect to A_2 implies that either $\partial U/\partial \pi_2 = 0$, or $\partial \pi_2/\partial A_2 = 0$ and $\partial U/\partial \pi_2 = 0$ is unreasonable.
[3] Note that $\bar{L} - L > 0$ is assumed to hold for simplicity and realism.
[4] The USDA collects data on off-farm income but they are not suitable for examining this phenomenon because income earned by farmers from working on other farms is included. Thus, the data reflect "reduced-form" interaction of demand and supply factors. That is, in periods of weak agricultural conditions, the demand for interfarm labor may decrease more than interfarm labor supply increases, so that off-farm income provides little indication of the phenomenon of interest. An appropriate examination requires data on time allocation by farm families.

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