Sustainability and Subsistence in Arctic Communities

Matthew D. Berman

Institute of Social and Economic Research
University of Alaska Anchorage
3211 Providence Drive
Anchorage, Alaska 99508, USA
e-mail auiser@uaa.alaska.edu

prepared for presentation to the

Western Regional Science Association
annual meeting
Monterey, California

February 1998

Sustainability and Subsistence in Arctic Communities

Introduction

Thirty years ago, Chance (1966) wondered if hunting and fishing traditions of the people of the Arctic Slope of Alaska would survive the transition from nomadic to village life. The oil boom of the 1980s brought change to the region to an extent neither Chance nor Arctic dwellers themselves might have predicted (Knapp and Morehouse, 1991). Yet despite a vigorous wage economy fueled by two decades of oil revenues that yields a per-capita income exceeding the national average, subsistence traditions remain strong. Average per-capita harvest of subsistence foods in Alaska's North Slope Borough still exceeds a pound per day (Fuller and George, 1997).

Arctic communities have continued their subsistence while taking advantage of the better opportunities for schooling and other public services provided in established villages by adopting new transportation technologies. Snow machines have replaced dog teams; power boats have replaced skin boats; airplanes are used by the more economically advantaged. The new technologies greatly expand the range of travel for a hunter in a day or weekend. But they require much more money for equipment and fuel.

Is the new mixed cash-subsistence economy sustainable? The question of sustainability here is not one of resource conservation, nor of whether local communities will have access to resources. Rather, it is whether people will have the time, money, and ability to continue subsistence while living in the permanent modern communities of the Arctic.[1] Although the cash economy of the Arctic Slope of Alaska is still strong, the future of resource development in the North is always uncertain, and public support for rural development and public assistance is waning in both Alaska and Arctic Canada. Neighboring communities without access to Prudhoe Bay tax revenues may already be vulnerable.

In this paper, I address economic conditions necessary for sustainability of the mixed subsistence-market economy of the North American Arctic. In the next section I introduce a general household production model of the modern subsistence economy and discuss how one might use the model to test hypotheses about sustainability. Then I elaborate a formal economic model to define relationships that may be empirically estimated and to generate statistical tests of sustainability hypotheses. Next, I estimate the main relationships of the model with data on residents of the northern Alaska and formally test sustainability hypotheses. I conclude by summarizing the implications of the analysis for sustainability of Arctic communities, and discuss important issues left for further research.

Sustainability and Household Production in the Arctic

In this section, I describe the general framework for modeling the mixed subsistence-cash economy of the Arctic, focusing on elements that are essential to a discussion of sustainability. A growing body of literature discusses the mixed subsistence-cash economy of rural northern Canada and Alaska and raises the question of whether this system -- and the cultures that depend on it -- will survive into the 21st Century (VanStone, 1960; Chance, 1966, 1987; Wolfe, et al., 1984; Dryzeck and Young, 1985; Stabler, 1990; Kruse, 1991; Kirkvliet and Nebesky, 1997). The question of whether wage work on balance complements or competes with subsistence has often been raised in these studies, and several authors have performed empirical analyses with data on employment and subsistence participation (Stabler, 1990; Kruse, 1991; Kirkvliet and Nebesky, 1997). However, none of the studies addresses the economic conditions necessary for sustainability.

---

[1] I use the term "subsistence" here to mean living off local resources of the land and sea as a way of life. Gathering of subsistence or "country" foods is just a part of subsistence living. The subsistence economy is an entire economic system based on household production and sharing of locally produced goods, with closely integrated social, cultural and spiritual dimensions (Wolfe, 1984).

A primary methodological issue with research on the relationship of subsistence to the market economy is the problem of *identification*. Households are likely to make tradeoffs between how much time to spend on subsistence and how much time working for pay, knowing that cash from work can be used in subsistence production. Empirical methods by themselves are not sufficient to identify whether subsistence and work are complements or substitutes. Consequently, testing hypotheses about sustainability requires use of a model which identifies separate structural relationships for each important household decision in a logically complete model of the economy.[2]

The starting point for modeling the subsistence economy is the household production model first articulated by Becker (1965). In the household, or home production model, household members combine inputs of time and market goods to create outputs of value to the household. Since time must be spent working for wages to purchase market inputs used in home production as well as to purchase consumer goods, a primary focus of the model is on the allocation of time between working for pay and working at home. Becker and others who developed the model further (see Gronau, 1986) addressed primarily home production of married women that substitutes for market consumption goods and services (e.g., child care, home-cooked meals). While one could look at the Arctic subsistence that way, a more effective analogy would be to turn the model inside out, and focus on purchases with wages of cash inputs for home production of subsistence products.

Subsistence households combine inputs of time and market goods such as fuel and ammunition, rifles, nets, boats, and snow machines, to find and bring home foods and other local resources. Household jobs and transfer payments provide money for the market inputs. I assume that the national and regional forces drive local labor markets, so that job availability and prevailing wage rates are exogenously determined. A key household decision is how to earn enough income working for pay while assuring adequate time left to hunt and to fulfill family responsibilities. Other important factors in household production -- assumed given in the short run -- are subsistence and job skills, and the demographic composition of the household.

In the short run, then, sustainability of the subsistence economy could be framed largely as a question of ensuring successful harvests of local natural resources to achieve consumption targets. To address long-term economic sustainability, however, one must look beyond current harvest success and consider as well the investments in subsistence "human capital" required to reproduce hunting skills, traditional ecological knowledge, and important cultural values associated with subsistence. In order to address these long-term issues, I examine specifically the roles of two key elements of Arctic subsistence economies: (1) sharing with other households, and (2) the amount of time spent on subsistence, or *time on the land*.

Sharing for diversification of harvest risk and for equity concerns has historically been a integral part of Arctic subsistence economies (Wolfe, et al., 1984; Brown and Burch, 1992). The dominant form of sharing in Arctic communities is generalized reciprocity (Sahlins, 1972). Sharing has both short-term and long-term implications for modeling the subsistence economy. In the short term, gifts to other households may not match receipts. In the long term -- over the life cycle -- reciprocity is preserved by the assumption that expected receipts equal expected gifts. Sharing may not be limited to subsistence harvests; the welfare of a household may also depend on receipts of market goods produced or purchased by other households. In addition, a household's subsistence production may be enhanced by use of another households' cash inputs. It is not necessary to address what the local "prices" might be for a tradeoff of market goods for subsistence goods, since they may be observed indirectly in the willingness of a household to trade time for money in a wage job.

In the long run, sharing and time on the land are both investments in reproducing important cultural values necessary for sustaining the subsistence economy, including solidarity, respect for elders, respect for animals, and traditional ecological knowledge. The household will invest in sharing and time on the land until the incremental benefits match the incremental costs. The long-run benefits of the investment in sharing come from supporting a system that involves reciprocal sharing of future harvests by other households in the community. Spending time on the land is an investment in increased future harvest success. For the community as a whole, these two investments are

[2]Kirkvliet and Nebesky (1997) reported statistical tests of simultaneity of wage work and subsistence, but did not discuss identification. Their approach is discussed below.

complementary. The present cost of sharing, of course, is the value of current consumption. For time on the land, the present cost is the *opportunity cost* of time in alternative activities: working for pay, family responsibilities, and leisure.

I hypothesize, therefore, that income and harvest success as well as traditionality and demographic characteristics of the household may affect the degree of sharing,. While both money income and subsistence production have "income effects" -- they increase the household ability to be generous -- the former has a "substitution effect". That is, higher household per-capita income reduces the advantage of the diversification of harvest risk available from sharing. I assume that time on the land depends on the wage or time at work (or at school), traditionality, and family obligations (demographic characteristics). If time at work is flexible, one would expect a negative effect of the wage on time on the land.

To summarize, I define sustainability in terms of the ability of households in the community to continue a high level of subsistence harvest and consumption and make the necessary investments to transmit important knowledge and cultural values to the next generation. I propose to measure sustainability with three key indicators: (1) household subsistence production, (2) the degree of sharing, and (3) time on the land.[3] While I acknowledge that no three indicators are sufficient to describe the whole system, these three measures nevertheless convey a great deal of information about the subsistence economy. Sustainability of the subsistence system is inferred if the level of exogenous or policy variables lies in the range needed to reach arbitrarily set minimums of each of the three indicators. In the short run, enough jobs at a high enough wage rates and adequate subsistence resources need to be available in order for the household to harvest enough to achieve a high level of consumption, given the prevailing household and community norms for sharing. In the long-term, traditionality and education are also needed to assure that households make adequate investments in time on land and sharing.[4]

A Household Production Model of the Subsistence Economy

The formal household production model of the Arctic subsistence economy is similar to that suggested but not elaborated by Kirkvliet and Nebesky (1997). To introduce the model, let me first define a set of variables:

M	consumption of market goods
S	consumption of subsistence goods
t_j	time spent in activity j; $j = S$ (subsistence), L (leisure), F (family), E (wage employment)
T	total time
C	total cost of market goods used in subsistence activities
K_k	knowledge (human capital) ($k = S, E$)
H	exogenous household and community demographic factors
Z	availability of game
X	subsistence production
w	wage rate

[3]Sustainability of a community can be defined as a set of conditions for the typical household, or for a certain number or proportion of households in a community. For example one might decide that at least 50 percent of households achieve all the sustainability conditions in order for the community to be considered sustainable.

[4]Investment in education is clearly an important element in success in the labor market, and involves household choices as well as policy decisions. The focus of this paper is on investments in subsistence rather than job skills, so I ignore the role of household education decisions.

Y	total household income
y_0	exogenous (non-wage and transfer) income
P_i	price of good ($i = M, C$)
R_M	purchases of market goods for consumption
R_C	purchases of market goods used as cash inputs for subsistence
g_i	sharing (giving) of goods ($i = M, C, S$); $g_i > 0$ means net gift of i
L	Traditionality -- preference for the traditional way of life

The household maximizes an expected utility function that depends on consumption of subsistence and market goods, and time spent in the alternative activities, and preferences:

$$U = U(M, S, t_S, t_L, t_F, t_E, L).$$

In pursuing maximization of U, the household is constrained by the available subsistence production technology and budget limits on money and time, as adjusted for prevailing norms about sharing. Subsistence production is uncertain, and assumed to depend on time, capital and operating costs (cash inputs), knowledge, and availability of resources:

$$X = f(t_S, C, K_S, H, Z) + e ,$$

where e is a random variable with a zero mean.

Purchases of all market goods and services may not exceed income. Income may be augmented above an exogenous level (transfer payments), by working for a wage that may vary with household education and demographic characteristics:

$$P_M R_M + P_C R_C \le Y = w(K_E, H)t_E + y_0 .$$

Finally, the sum of time spent in subsistence, work for pay, family responsibilities, and leisure may not exceed the total time available:

$$t_S + t_L + t_F + t_E \le T .$$

To close the model, one notes that purchases and sharing limit commodities available for use. Theoretically, one can share market consumption goods, subsistence cash inputs, or subsistence harvests, yielding three constraints:

$$M \le (1 - g_M)R_M ,$$

$$C \le (1 - g_C)R_C ,$$

$$S \le (1 - g_S)X .$$

Sharing here is modeled as a net fraction g_j of production or purchases of type j. The sharing fraction, g_j, may be positive (signifying net gifts) or negative (net receipts). Sharing of different types of goods may not be independent. That is, a household that is a net recipient of cash inputs for subsistence may be a net giver of subsistence products.[5]

[5]In fact, this may be the case on a bilateral basis, as households offering use of equipment for subsistence may expect some share of harvests using that equipment (Kofinas, 1997). To be complete, the model should include the receipts that the household obtains harvest from the other households' sharing of harvests. Although the sharing rates are assumed fixed in the short run, complications might still arise if the prospect of receipts from other households affected time and

Short-run optimization

In the short run that sharing rates, g_j, and skills, K_k, are exogenous. Also exogenous in both short and long run are prices, w, y_0, T, H, and L. Combining constraints, 2, 3, and 4 into one constraint on total time, one may write the household's decision as the allocation of time and consumption that maximizes

$$
\begin{aligned}
V &= U(M, S, t_S, t_L, t_F, t_E, L) \\
&\quad - l\left[P_M M/(1-g_M) + P_C C/(1-g_c) - w(T - t_S - t_L - t_F) - y_0\right] \\
&\quad - m\left[S/(1-g_S) - f(t_S, C, K_S, H, Z) - e\right]
\end{aligned} \tag{1}
$$

where l is the Lagrange multiplier for the time constraint, and m is the Lagrange multiplier for the subsistence production technology.

The solution to equation (1) is the indirect expected utility function

$$W(P_M, P_C, w, y_0, g_M, g_C, g_S, T, K_S, H, Z, L) \tag{2}$$

where the two constraints are binding, and the following first-order conditions for equation (1) hold:

$$V_M = 0 = U_M - l\ P_M/(1-g_M)$$

$$V_S = 0 = U_S - m/(1-g_S)$$

$$V_C = 0 = -l\ P_C/(1-g_C) + mf_C$$

$$V_{t_S} = 0 = U_{t_S} - lw + mf_{t_S}$$

$$V_{t_L} = 0 = U_{t_L} - lw$$

$$V_{t_F} = 0 = U_{t_F} - lw$$

These first-order conditions equations may be combined to describe an optimal allocation of time in the indirect utility function where

$$U_{t_S} + U_S(1-g_S)f_{t_S} = U_S(1-g_S)f_C\,\frac{w(1-g_C)}{P_C} = U_M\,\frac{w(1-g_M)}{P_M} = U_{t_F} = U_{t_L} \tag{3}$$

Equation (3) states that the household allocates time so that the (subjective) value of an additional hour is the same in four respective activities: subsistence, working to earn money for subsistence, working to earn money to buy market consumption goods, family activities, and leisure.[6]

The equilibrium (3) combines three separate and familiar microeconomic relationships.

The first two terms express the marginal rate of technical substitution of time for money in subsistence:

$$\frac{f_{t_S}}{f_C} = \frac{w}{P_C/(1-g_C)} - \frac{U_{t_S}}{U_S(1-g_S)f_C} \tag{3a}$$

If household members do not value their time engaged in subsistence activities beyond its contribution to subsistence production, and there is no sharing of cash subsistence inputs, then

---

money allocation decisions. I assume that generalized reciprocity dominates for subsistence goods, and the household expects no specific short-run return for sharing with other households.

[6]Note that while exogenous variables H, Z, L, and y_0 do not appear in equation (3), all partial derivatives of U may depend on H and L, and f_C and f_t may depend on both H and Z.

equation (3a) reduces to the equality between the marginal rate of technical substitution and the price ratio:

$$\frac{f_{t_S}}{f_C} = \frac{w}{P_C}$$

When the household places additional value on time on the land, then the tradeoff between time and money is altered in favor of more time and less money used in subsistence production. Interestingly, a higher rate of sharing of subsistence harvests increases the second term of equation (3a), effectively reducing the marginal value of time relative to money. For example, a hunter who values time on the land derives value from the time spent hunting (but not money spent on the hunt), even if the harvest is given away to others. This effect is enhanced further to the extent that the household sharing harvests receives shared cash inputs to subsidize the hunt. This suggests that sharing may provide an added incentive to spend time on the land, a relationship that may prove symbiotic as time on the land builds subsistence knowledge over the long term.

The second and third terms of equation (3) express the equality of the marginal rate of substitution of subsistence cash inputs to market consumption goods and the price ratio (appropriately adjusted for sharing):

(3b) $$\frac{U_S f_C}{U_M} = \frac{P_C/(1-g_C)}{P_M/(1-g_M)}$$

Finally, the last three terms express the respective equalities -- of lesser interest in this case -- of the marginal rates of substitution of leisure time and family time to market consumption goods, and their price ratio.

(3c) $$\frac{U_{t_F}}{U_M} = \frac{U_{t_L}}{U_M} = \frac{w}{P_M/(1-g_M)}$$

The indirect utility function (2) has negative partial derivatives with respect to its first two arguments (prices), and non-negative partial derivatives with respect to all other arguments (except *H*, which may be positive or negative). If households can not vary work hours to participate in subsistence, then corner solutions likely for t_E. Additional job security and flexibility variables should be included in the indirect utility function (2).

Long-run optimization

In the long run, sharing and skills are endogenous. Among types of sharing, gifts of subsistence harvests are of greatest interest, since these are most directly tied to cultural values and tradition. The basic premise is that sharing of subsistence harvests (g_S) and time on the land (t_S) are investments in traditional knowledge; e.g.,

$$\frac{dK_S}{dt} = h(t_S, g_S); h_{t_S} > 0, h_{g_S} \geq 0.$$

We can not observe *K* directly, but may observe g_S and t_S. The long-run equilibrium implies a revised first-order condition with respect to t_S, as well as an additional equation for g_S.[7]

To specify the effect of reciprocal sharing in the long run, let $\overline{X}$ represent the expected harvest of a household with similar economic and demographic conditions. Then the harvest constraint might be rewritten as

$$S \leq (1-g_S)X + g_S\overline{X} = S \leq X - g_S e\ .$$

[7]Another important investment in subsistence skills is learning the indigenous language. Fluency in the native language may be required for understanding the more subtle aspects of traditional cultural and ecological knowledge.

That is, over the long run, the household expects its net gift to equal only its unexpected net good fortune. This simplifies the model by making short-run time allocation independent of sharing. The long-run first-order condition for g_S is:

$$V_{g_S} + \tilde{V}_{K_S} h_{g_S} = -me + \tilde{V}_{K_S} h_{g_S} = 0 ,$$

or

(4) $$\tilde{V}_{K_S} h_{g_S} = eU_S ,$$

where $\tilde{V}$ represents the present value of all future (indirect) utility.

The left-hand side of equation (4) represent the benefits of a small increase in the rate of sharing in terms of future subsistence consumption, while the right-hand side represents the marginal cost in terms of present consumption. If utility is concave in total consumption, the equation suggests that larger current harvests, higher money income, and more uncertain future harvest (or income) will increase the value of additional future expected relative to present serendipitous consumption.

The new long-run first-order for time on the land is:

$$V_{t_S} + \tilde{V}_{K_S} f_{t_S} = 0 = U_{t_S} - lw + \left(m + \tilde{V}_{K_S}\right) f_{t_S} .$$

The long-run best allocation of time adds a third term to the left-hand side of equation (3) representing the benefit of time on the land for increasing future harvests:

(5) $$U_{t_S} + U_S f_{t_S} + \tilde{V}_{K_S} f_{t_S} = U_S f_C \frac{w(1-g_C)}{P_C} = U_M \frac{w(1-g_M)}{P_M} = U_{t_F} = U_{t_L} .$$

Equation (5) implies a new marginal rate of technical substitution between time and money in subsistence production:

(5a) $$\frac{f_{t_S}}{f_C} = \frac{U_S}{\left(U_S + \tilde{V}_{K_S}\right)} \frac{w}{P_C/(1-g_C)} - \frac{U_{t_S}}{\left(U_S + \tilde{V}_{K_S}\right) f_C}$$

The first term of the long run equation (5a) multiplies the corresponding term in the short run equation (3a) by the ratio of current to current plus future marginal utility of subsistence consumption, while the denominator of the second term replaces current marginal utility of consumption by current plus future consumption. By adding the present value of future subsistence generated by today's time on the land to the denominator, the long-run equilibrium favors substitution of time for money in subsistence.

Sustainability conditions

As discussed above, I define sustainability in terms of a set of exogenous or policy variables that achieves and maintains arbitrary minimum levels of three related indicators: (1) household subsistence production, (2) the degree of sharing, and (3) time on the land. Equation set (3) -- (5) in the long run -- and equation (4) contain five equations for how households combine time and money and share the harvest to meet their needs. Most important are equation (3a) -- (5a) in the long run -- expressing the tradeoff of time and money in subsistence, equation (3b) describing substitution of market for subsistence consumption, and equation (4) defining the net benefits of sharing.

Figure 1 illustrates how the primary exogenous variables -- wage rates, jobs, and availability of resources -- could achieve sustainability objectives in the short run for a representative household. The horizontal axis represents total time available for wage work and subsistence, considering time desired for family and leisure as given in equation (3c). The vertical axis represents the amount of money used in subsistence. The downward-sloping line BB' represents the budget allocation of time and money for subsistence. That is,

(6) $$BB' = P_C C \le (1-g_C)\left[y_0 + w(K_E, H)t_E - P_M M/(1-g_M)\right],$$

where the value of *M* is given by the solution to equation (3b). The budget line BB' includes transfer income, and has a slope representing the amount of money made available for subsistence for each additional unit of work time. The magnitude of the slope depends directly on the wage rate.[8]

The downward-sloping curve S_0 in Figure 1 represents the household's time and money tradeoff required to achieve the minimum harvest standard, given the availability of subsistence resources and taking current sharing into account. Technically, S_0 is the isoquant for the target subsistence production whose slope is given by equation (3a). As drawn in Figure 1, the household achieves the standard, because there is a range on the horizontal (time) axis where the budget line is higher than the harvest requirements curve.[9] The household in this case would choose an allocation of time represented at point A, where the budget line BB' is tangent to a parallel curve above S_0, labeled S_1, that represents a more ambitious time and money tradeoff. A decline in real wage rates would flatten the budget line, making it more difficult for the household to achieve the standard. A decline in resource availability would shift the curve S_0 upward and to the right, indicating that more time and money would be required to obtain the same harvest.

Figure 2 illustrates how well the short-term equilibrium point A meets the long-term sustainability objectives of time on land and sharing. The minimum time on the land can be represented in Figure 2 as the vertical line T_0. Only points to the right of T_0 are sustainable in the long run. To meet the sharing target in this case, the minimum harvest has to increase so that households will be willing to give away more of the harvest, shifting the time-money tradeoff curve upward from the curve labeled S_0^{SR} to the curve S_0^{LR}. While the household at point A still harvests more than needed to meet the greater long-run sustainable harvest target, it spends insufficient time on the land.[10] That is, a sustainable subsistence economy may be technically feasible, yet not selected by households.

Several policies directly affect this situation. First, a reduction in transfers shifts the entire budget line down and to the left, making it more difficult for the household to finance subsistence. Reduced traditionality -- for example, loss of fluency in the native language -- makes it more difficult to achieve the time on the land objective by reducing the enjoyment of time on the land. This would be represented in Figure 2 by tilting the subsistence production tradeoff S_1 toward the vertical axis, so that more money and less time would be used to obtain the same harvest. Weakening of a traditional cultural orientation in the household would also make it more difficult to achieve the sharing objective, by requiring subsistence production to rise even higher -- outward shift of curve $S_0^{LR\,--}$ for the household to be willing to share enough.[11] Finally, improved education might raise the wage, steepen the budget line, and making all targets more attainable by reducing the amount of work time needed to finance subsistence production.

Empirical Tests of the Model

Households may be observed selecting point A in isoquant S_1 in Figure 2, combining time and money to produce a subsistence harvest. In principle one can estimate each of the five short-run equations of equation set (3) and equation (4), and each of the two long-run equations. However, an equation may only be estimated in practice if the variables that permit identification of the equation may actually be observed in the available data. One can also estimate reduced-form equations with

[8] If jobs are limited, or if only part-time work can only be obtained (constraint on t_E), then the budget line hits a ceiling representing the maximum money available.
[9] The subsistence harvest sustainability criterion could be represented equivalently in the figure as the minimum budget line needed in order to harvest the target amount.
[10] The slope of the isoquants S_0^{LR} and S_1 in Figure 2 are given in by the long run equation (5a).
[11] Loss of traditional orientation might also increase the relative preference for market consumption over subsistence consumption. This would effectively flatten the budget line in Figure 1, making it more difficult to finance subsistence activities.

just exogenous variables. However, estimation of structural equations allows one to observe transparently how exogenous and policy variables affect sustainability outcomes.

In this section I first describe the data available for the study and discuss which structural equations can be identified and estimated with the data. Next, I summarize estimation results. Finally, I discuss the sustainability conditions implied by the results.

Data sources and identification of structural relationships

Two primary data sources are available to estimate the model and examine sustainability hypotheses. Data on economic and demographic variables and aggregate indicators of total subsistence participation are available at the household level from a census of Alaska North Slope Borough residents. The data were collected between June 1988 and April 1989 from face-to-face interviews in Barrow and seven outlying communities, with a response rate of 91 percent (Nebesky, 1989). This is the same original data set analyzed by Kruse (1991) and Kirkvliet and Nebesky (1997).

In addition to the North Slope Borough census data, detailed subsistence harvest records covering the same time period as the economic data in the census are available for a random sample of 120 Barrow households (Braund et al., 1988). These sample households are a subset of the Barrow census population. The data from the two sources were matched with a unique household identifier, yielding matched data for 100 households, or an 84 percent success rate.[12]

A particular equation of the model is in general identified if it omits at least one of the model's list of exogenous variables for each endogenous variable it includes as an explanatory variable.[13] Of course, an equation can only be estimated empirically if the variables needed to identify it are observed in the data. While identification also depends on specific functional forms assumed for the utility function *U* and the subsistence production function *f*, it is preferable to avoid having to rely on restrictive assumptions about functional forms to identify the model.

Exogenous variables that are measured or may be inferred in the census data include total household size, and ethnicity, age, sex, marital status and educational attainment for household members age 16 and over. No data on price variation among communities are available, but I assume that all prices are generally higher in outlying villages than in Barrow, which has daily commercial jet air service. No household data on sharing of market consumption goods or subsistence cash inputs are available.

Endogenous variables observed in the census data include months worked and higher education enrollment for each adult in the household and whether the individual spent more time in subsistence than working (in three categories). The percent of meat and fish consumed from the household's own hunting and fishing efforts is available as an index of subsistence consumption, and sharing of subsistence harvests with other households -- exogenous in the short run -- is available as a percent of total harvest and in ordered categories. I construct an index of household subsistence production by combining these two indicators.[14] In addition, total quantity of each subsistence product, harvest date, location, household participants, and time in field for each harvest event are available for the random sample of Barrow households.

Given the data available, equations can be estimated for X, t_S, and g_S. I estimate a subsistence isoquant S_1 in Figure 1 as:

$$X = f\left(t_S, Y, H, Z, L\right) \qquad (7)$$

---

[12]I am indebted to Jack Kruse and Steve Braund for creating this matched data set.

[13]This is the order condition for identification (Fisher, 1966). Identification is also possible using restrictions on the coefficients and on equation variances, but this usually requires imposing assumptions about functional forms.

[14]The index is defined as consumption divided by one minus the fraction given away. This index of subsistence production places in the background the traditional role of women as gatherers of plants, food preparers, and makers of clothing. To the extent that participation in these activities is necessary for sustainability of the subsistence economy is an important question left for further research.

where the best indicator for *L* observed in the data is the household gift share, g_S. This specification differs from the one analyzed in equation (1) in that it substitutes *Y* and *L* (and *H*) for the unobserved *C*, using equation (3b). Non-negative coefficients are expected for time, income, and sharing (indicating a preference for the traditional way of life).

To obtain an equation for time on the land one needs to equate the isoquant S_1 with the budget line BB' to estimate the household's point A in Figure 2. This adds the variables in equation (3a) to those in equation (7). Some assumption about the form of the subsistence production function is necessary in order to identify the equation. Specifically, the marginal rate of technical substitution of time for money must be independent of *X* and *Z*, so that these variables can be omitted from the equation.[15] This yields the following structural equation:

(8) $$t_S = t_S(w, Y, H, L); \P t_S / \P w \le 0, \P t_S / \P Y \ge 0 .$$

Equation (8) can be estimated for individuals or households. However, specialization of roles within households means that conclusions about allocation of individuals' time may not hold for households as a whole.[16]

As discussed above, the following structural relationship derives from solving equation (4) for g_S:

(9) $$g_S = g_S(Y, H, X, L); \P g_S / \P Y \le 0, \P g_S / \P X \ge 0 .$$

In this case, however, *L* is not observed. Sharing and time on the land also depend on the household's expected future values of all the variables in equation (1). One observes only current values of *Y* and *X*, so I assume they represent the best estimates of expected future values. This makes it impossible to identify the effect on t_S of enjoyment of time on the land in the short run from the effect of long-run investment in harvest skills.[17]

Results

I estimated equations (7), (8), and (9) using the North Slope Borough census data on all eight villages. In addition, I estimated equations for subsistence time using the sample of Barrow households. Since the household wage and non-wage income are not observed directly, I estimated these variables by regressing total household income on a constant and the number of months worked by community, sex, marital status, ethnicity, self-employed status, and three age and four education categories. The results provided a good fit to the data, yielding an R^2 of 0.72 and an overall mean (marginal) wage rate of about $2200 per month worked.

Table 1 shows the two-stage least squares estimation results of a loglinear form of equation (7) for subsistence harvest. Coefficients on time and money are robust to the specification, with an

---

[15] This assumption holds for homogenous production functions, for example.

[16] Kirkvliet and Nebesky (1997) estimated an equation for t_S for individuals of the following form:

$$\frac{t_S}{t_E} = f(t_E, g_S, H).$$

They acknowledged the possible simultaneity of the model but did not describe or identify structural relationships. They assumed away the obvious errors in variables problem with their equation by assuming that t_E was not influenced by t_S based on the failure of an exogeneity test statistic to reject a null hypothesis of independence of influence of the categorical t_S on the integer t_E. The null hypothesis should be reversed: time allocation is simultaneous unless rejected by statistical evidence. Their test statistic -- $\chi^2(1)=1.401$ -- has a probability value of 0.24, or a 76 percent probability of simultaneous influence.

[17] Technically, a discount rate should also be included as an exogenous variable in equations (8) and (9) for time on the land and sharing, but no additional variables are available that would measure variation in discount rates among households.

estimated time elasticity of about 0.6 and a money elasticity of about 0.5. Inupiat households, as expected, are much more efficient at producing harvest with money and free time. The equation shows slightly increasing returns to scale, suggesting that larger households are a little more efficient in using time and money. When g_S is included as a measure of traditionality and assumed exogenous in the equation for percent of household consumption, it is positive and highly significant. It is insignificant when assumed endogenous in the consumption equation, but positive and significant in the harvest index equation.[18]

Table 2 shows three specifications of equation (8) for the allocation of time. All are estimated as censored regressions to take account of the practical constraints on the time budget. The dependent variable in the first column of Table 2 is the average months not worked per adult in the houshold (e.g., 12 times the number of adults minus total months worked). This is the only quantitative measure of the amount of time available for subsistence activities observed in the North Slope Census data, and, as such, is used to measure the time input to subsistence harvests shown in Table 1. The coefficients in the last two columns of Table 2 are estimated from the survey sample of Barrow households. The dependent variables in the second column is the total household time spent on meat and fish harvesting trips, converted to number of person-days. The final column shows an equation for household person-days spent hunting caribou, the major big-game species on the North Slope.

All three time allocation equations show a negative association with the wage, as the theory predicts. Because the wage is not observed directly, and has to be estimated from observed time and income, a separate coefficient on income cannot be identified in any of these equations. The coefficient on the wage for the equation in the second column is -0.1136, in units of dollars per month per person. This result suggests that an increase of $100 in the average monthly earnings per worker would yield a decrease of 11.4 days per adult in time on the land. While the results in the first column suggest that Inupiat adults work an average of 3.3 months less annually than non-Inupiat housholds, there is no significant difference in the amount of time spent hunting and fishing, after controlling for wage and demographic differences.

Estimates of equation (9) for the percent of meat and fish harvests given away to other households are shown in Table 2. Three different specifications are reported: uncensored (two-stage least squares), taking into account the constraint that the sharing percentage may not be negative or greater than 100 percent (tobit), and dividing the observed sharing percentages into four categories (ordered probit). All three equations use instrumental variables for the endogenous household income and harvest. The pattern of coefficients is similar across the three specifications. However, the coefficients are larger and more significant when the censoring of the dependent variable is taken into account. In particular, income is negative and highly significant, consistent with the hypothesis that reciprocal sharing is more valuable to lower income households. Larger households share less, as do highly educated households. The latter variable, referring mostly to teachers and high-level administrators, indicates a high long-run income. A coefficient for Inupiat households was close to zero and not statistically significant, suggesting no important differences in sharing patterns across ethnic groups.

Sustainability Conditions

What do the results presented in Tables 1, 2, and 3 imply for the sustainability of the subsistence economy of Alaska's Arctic Slope? Figure 3 helps focus the discussion by illustrating some of the key empirical findings with respect to the time and money requirements of subsistence. It shows the time and money budget for an example household, along with the time and money

---

[18]An equation with exogenous g_S was not estimated for the harvest index because the way that the index was constructed creates an obvious errors in variables problem. These equations were estimated using only data on the households that reported that they consumed some subsistence harvest from their own efforts. The equations were tested for sample selection bias. The correlation of errors of the harvest equation with the errors of a probit equation explaining subsistence participation was only 0.08, with a probability of level of 0.22 of rejecting the null hypothesis of no selection effect. Correcting for selection would raise the standard errors by less than one percent. I chose to report the efficient but possibly very slightly biased results estimated without the sample selection effect.

tradeoff that could achieve a target harvest equal to 50 percent of the total household meat and fish consumption (before sharing is deducted but not counting receipts from other households). For this illustration, I have chosen a Barrow Inupiat household with three adults and two children, whose adults earn the North Slope average wage rate. It assumes a long-term sharing target of 30 percent of total harvest.

The downward-sloping dashed straight line represents the budget constraint of the household. Its slope equals -$6,600 per month, the earnings lost if the household average time worked declines by one month each year. The budget constraint shown in Figure 3 differs from the budget line BB' in Figure 2 by leaving out the household's allocation of money between subsistence and consumption, which is not observed in the data. The downward-sloping curve represents the tradeoff of time and money -- an isoquant of the household production function -- that the household needs to be able to harvest the target amount. It is related to the curve S_0 in Figure 2 but leaves out the subjective value of time on the land.

In Figure, the isoquant crosses the budget line slightly, indicating that the target is technically attainable under the resource availability and economic conditions prevailing in the data. However, the figure shows clearly that there is little room for unfavorable change: a 10 percent decline in the real wage (flattening the budget line) or in harvest per unit of effort (raising the time and money needed), for example, would render the target infeasible.

Although the typical household can technically achieve the example sustainability target for harvest, whether it will in fact do so depends on its subjective valuation of subsistence time. Using the coefficients in the first column of Table 2 to solve for t_S in equation (8), one obtains 6.67 average months not working per adult for this sample household. The household's desired time allocation is shown as the vertical line T_0 in Figure 3. At time T_0, the budget line and the production isoquant appear to intersect. The economy allows this sample household earning the average earnings per month to meet the sustainable harvest target, but just barely.

One could also solve for t_S using the second column of Table 2 to estimate the household's predicted time on the land. Assuming that the household contains one elder, the household spends about 80 days per adult in the field, a quite respectable number. While the economy appears to allow the example household sufficient time on the land, predicted sharing is far less than the target of 30 percent of harvests. Using the coefficients for any of the specifications of g_S in Table 3 yields an estimated share given away of roughly 15 percent, or about one-half of the target.

Conclusions

In this paper I defined sustainability of a mixed subsistence-cash economy in the short and long runs in terms of harvest amount, time, and sharing criteria. I discussed how to identify and estimate empirically the relationships needed to determine if a community meets the sustainability criteria, and estimated a complete set of equations for each of the three key relationships for residents of Alaska's North Slope Borough. I illustrated how the equations could be applied in practice with an example household.

In the illustration, the example household barely meets the harvest target, appears to achieve any reasonable time target, but falls short of the sharing target. Sustainability of a community economy depends not on the performance of a single example household, no matter how representative, but rather on the distribution of households with respect to the criteria. However, this paper provides the tools with which to perform that analysis.

Although the general approach may be applied to any mixed economy characterized by cash-supported subsistence hunting and fishing, specific applications to other regions of the Arctic and Subarctic must take local conditions into account. For example, the North Slope Borough -- the major year-round employer in the study region -- has a liberal leave policy for subsistence. Year-round work for the borough government or school district still allows substantial time for subsistence activities. Few other areas where subsistence is still practiced have as strong a cash economy or as much local control over subsistence resources as the borough.

Any analysis that tries to make statements about the future is based on uncertain assumptions of future conditions relative to the present. For example, new technologies that provide to travel farther and faster with less money, could enhance the prospects for meeting the harvest target of the subsistence economy (although it may not assure adequate time on the land). Preferences also could change, making the question of sustainability moot. Though unlikely given the resilience of subsistence through the profound changes of the 20th Century, it is possible that Arctic residents may no longer care to continue their subsistence even if they have the time and money to do so.

Finally, the analysis is incomplete in that it does not adequately address issues of division of labor within household. Specifically, women's home production of clothing and food preparation have largely been replaced by market commodity alternatives, while markets have not been allowed to develop for country foods. Women can earn enough with full-time wage work to purchase clothing and household appliances that substitute for subsistence activities, and still have money left to supply cash inputs for men's hunting. In this respect, empirical findings of sustainability may not apply to developing areas with lower prevailing wage rates for women. The question is still open whether it will be necessary to retain or recover women's traditional skills to sustain the subsistence economy if the wage economy falters.

References

Becker, G., "A Theory of the Allocation of Time," *Economic Journal* 75 (1965): 493-517.

Braund, S. et al., *North Slope Subsistence Study: Barrow, 1987* (Anchorage: U.S. Dept. of the Interior, Minerals Management Service, Final Technical Report No. 133, 1988).

Brown, T., and E. Burch, Jr., "Estimating the Economic Value of the Subsistence Harvest of Wildlife in Alaska," in *Valuing Wildlife in Alaska*, ed. G. Peterson (Boulder, Colo: Westview, 1992).

Chance, N.A., *The Eskimo of North Alaska*, New York: Holt, Rinehart and Winston, 1966.

Chance, N., "Subsistence Research in Alaska: Premises, Practices, and Prospects," *Human Organization* 46 (1987): 85-89.

Dryzeck, J., and O. Young, "Internal Colonialism in the Circumpolar North: The Case of Alaska," *Development and Change* 16 (1985): 123-45.

Fisher, F.M., *The Identification Problem in Econometrics* (New York: McGraw-Hill, 1966).

Fuller, A., and C. George, *Evaluation of Subsistence Harvest Data from the North Slope Borough 1993 Census for Eight North Slope Villages: For the Calendar Year 1992* (Barrow: North Slope Borough, Department of Wildlife Management, 1997).

Gronau, R., "Home Production -- a Survey," in *Handbook of Labor Economics*, ed. O. Ashenfelter and R. Layard (New York: North Holland, 1986).

Kirkvliet, J., and W. Nebesky, "Whaling and Wages on Alaska's North Slope: A Time Allocation Approach to Natural Resource Use*," Economic Development and Cultural Change* 46 (1997): 651-665.

Knapp, G. and T. Morehouse, "Alaska's North Slope Borough Revisited", *Polar Record* 27 (163): 303-312, October 1991.

Kofinas, G. Unpublished field notes, October 1997.

Kruse, J. "Alaska Inupiat Subsistence and Wage Employment Patterns: Understanding Individual Choice," *Human Organization* 50 (1991): 3117-26.

Nebesky, W., *North Slope Borough Census of Population and Economy* (Barrow: North Slope Borough, Department of Planning and Community Services, 1989).

Sahlins, M., *Stone Age Economics* (Chicago: Aldine-Atherton, 1972).

Stabler, J., "A Utility Analysis of Activity Patterns of Native Males in the Northwest Territories," *Economic Development and Cultural Change* 39 (1990): 47-60.

VanStone, J. "A Successful Combination of Subsistence and Wage Economies on the Village Level," *Economic Development and Cultural Change* 8 (1960): 174-91.

Wolfe, R., et al., *Subsistence Based Economies in Coastal Communities of Southwest Alaska* (Anchorage: U.S. Department of the Interior, Minerals Management Service, 1984).

Table 1. Household Harvest Equations

(t statistics in parentheses)

Dependent variable	Log of percent of HH meat and fish from own harvest times household size	Log of percent of HH meat and fish from own harvest times household size	Log of total household meat and fish harvest index
Specification	Two-stage least squares	Two-stage least squares	Two-stage least squares
Jointly determined variables			
Log of one plus adult months not working	0.617 (9.71)	0.622 (9.28)	0.613 (9.65)
Log of total household income	0.509 (6.87)	0.538 (6.83)	0.494 (6.61)
Log of one plus percent of meat and fish harvests given away			0.364 (3.69)
Predetermined variables			
Constant	-2.863 (-3.46)	-2.845 (-3.23)	-2.700 (-3.24)
Inupiat household	0.920 (5.47)	1.225 (7.16)	0.917 (4.54)
Log of one plus percent of meat and fish harvests given away	0.236 (7.18)		
Goodness of fit	$R^2 = 0.523$	$R^2 = 0.469$	$R^2 = 0.521$
Observations	776	783	778

Table 2. Time Allocation Equations

(t statistics in parentheses)

Dependent variable:	Average months not working per adult in hh	Total household members' hunting and fishing days	Total household members' caribou hunting days
Specification:	Tobit (<0, >12 censored)	Tobit (<0, >365/ adult censored)	Tobit (<0 censored)
Predetermined variables			
Constant	-0.0098 (-0.02)	186.64 (2.61)	-14.96 (-0.23)
Average household wage	-7.56×10^{-4} (-5.10)		-4.26 x 10-2 (1.69)
total household wage (average wage x adults)		-0.1136 (-7.02)	
Number of children under 16	0.232 (2.88)	-29.39 (6.04)	
Number of youth age 16-20	1.449 (6.45)		
Number of adults age 21-64	0.835 (5.70)	341.77 (7.19)	
Number of elders 65 and over	2.993 (9.22)	176.37 (3.39)	
Number of married persons			53.13 (1.91)
Inupiat household	3.303 (11.64)		
Sigma	3.734 (39.07)	237.31 (13.23)	2244.28 (9.80)
Goodness of fit	LR = 0.207	LR = 0.347	LR = 0.069
Observations	1272	84	84

Table 3. Equations for Percent of Meat and Fish Harvests

Given Away to Other Households

(t statistics in parentheses)

Specification	Two-stage least squares	Tobit (<0, >100 censored)	Ordered probit (0, 0-15%, 15-30%, >30%)
Jointly determined variables			
Per capita household income	-9.34×10^{-5} (-1.65)	-4.55×10^{-4} (-4.01)	-2.987×10^{-5} (-7.85)
Index of hh meat and fish harvest	0.318 (15.10)	0.625 (14.86)	0.00718 (5.22)
Predetermined variables			
Constant	-6.189 (-2.49)	-11.467 (-2.46)	0.305 (1.89)
Household size	-1.089 (-3.07)	-2.694 (-4.07)	-0.0129 (-0.55)
Number of hh members with postgraduate degrees	-4.767 (-3.41)	-9.271 (-3.67)	-0.0986 (-1.07)
Sigma		31.841 (32.79)	
mu(1)			0.450 (15.58)
mu(2)			0.906 (22.09)
Goodness of fit	R^2 = 0.487	LR = 0.398	LR = 0.096
Observations	1144	1278	1279

Figure 1. Sustainability of the Subsistence Economy in the Short Run

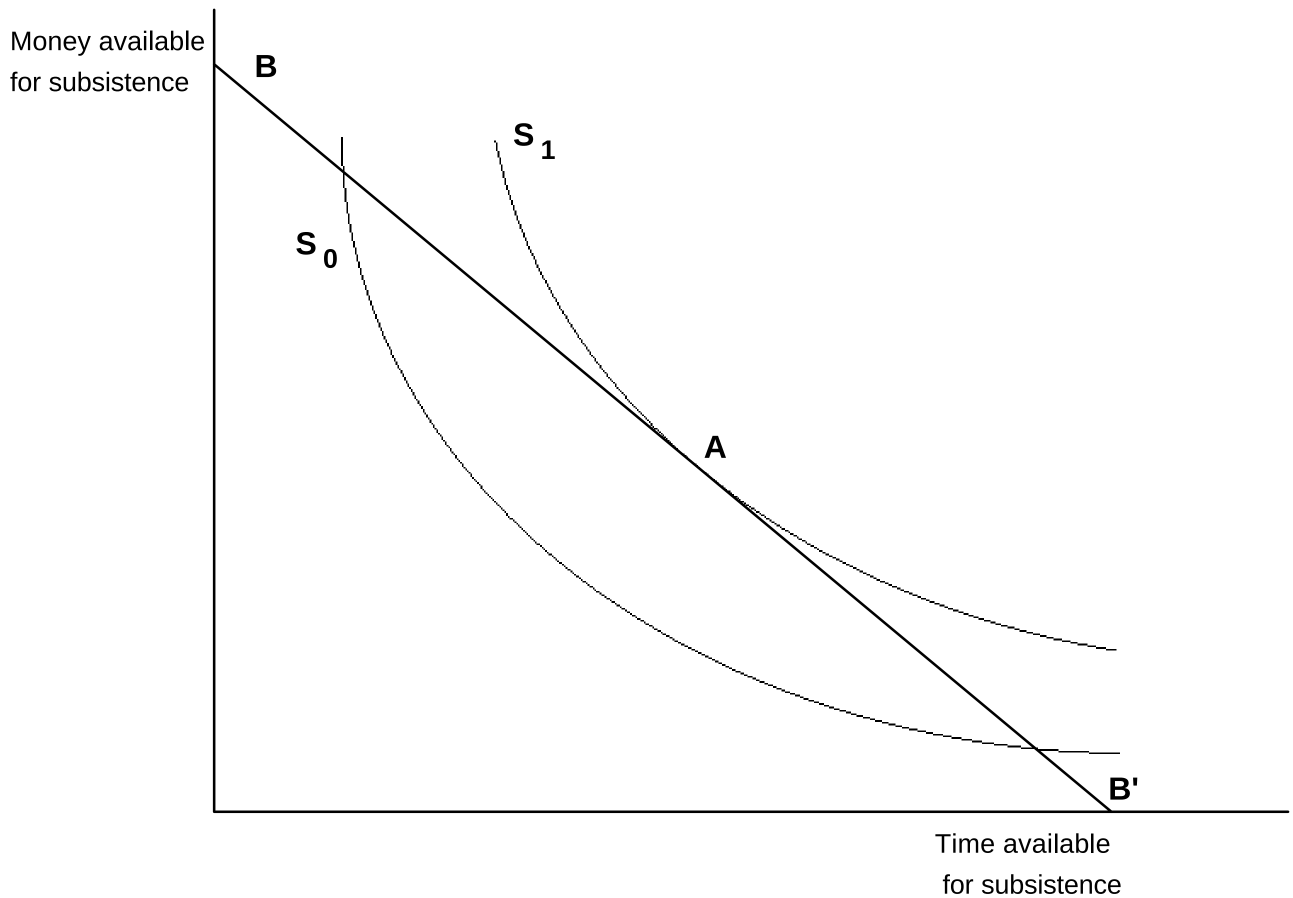

Figure 2. Sustainability of the Subsistence Economy in the Long Run

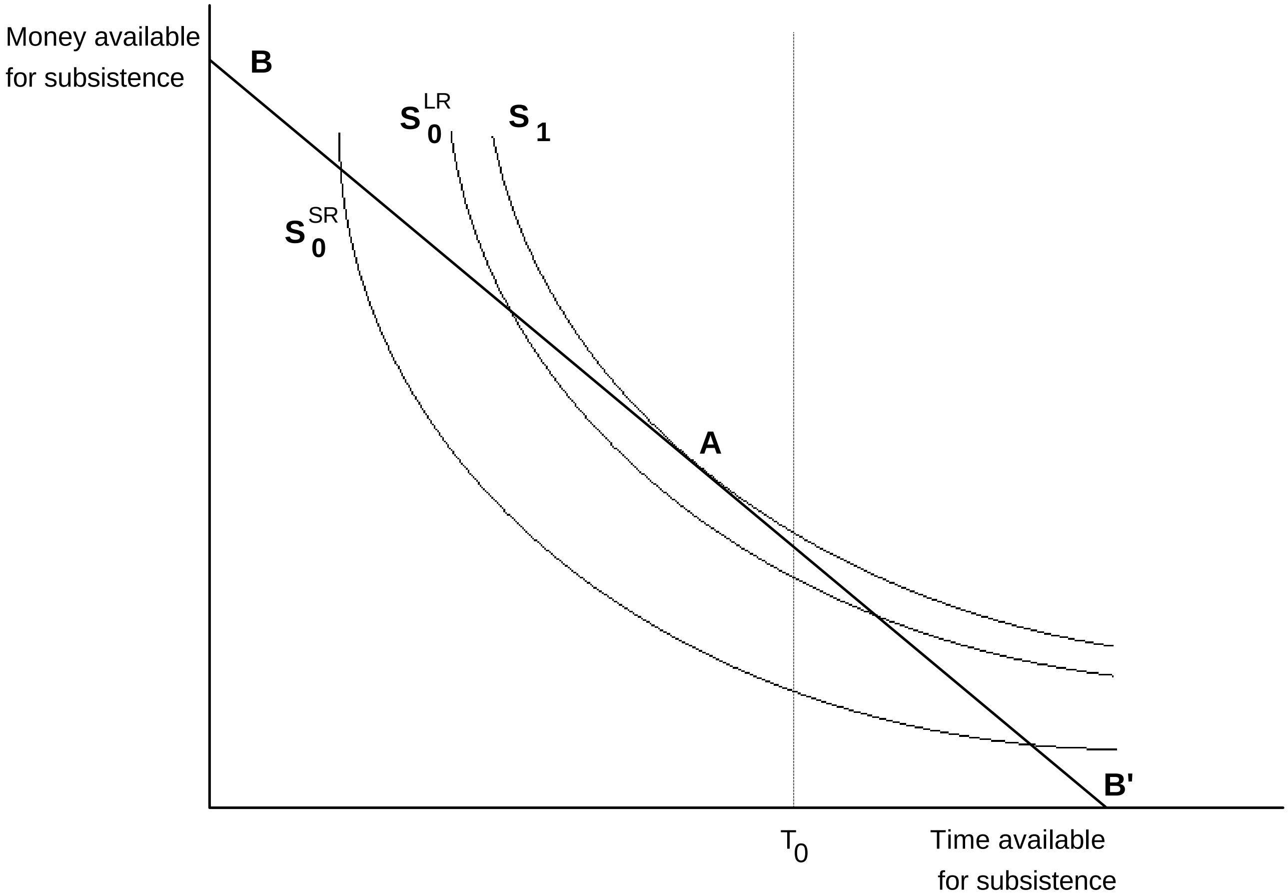

Figure 3. Time and Money Available to Barrow Household Versus Amount Needed to Achieve 50 Percent Harvest Target

Household with Three Adults, Two Children, Earning Average Wage Rate