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Professional paper No. P-1725 of the Agriculture Experiment Station, Oklahoma State University

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The forest resources of the thirteen southern states (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia) are in the midst of a series of changes that will have a more profound impact than any they have experienced in the past. These changes include the availability of new technology to grow and utilize the resources of the forest. The demand for forest products has risen to the point where it is reflected in increased raw material prices throughout the region. Scarcity has become a long-term concern for the industry in the region for the first time since the beginning of the century. And finally, because of the proximity of southern forests to the current and future markets of the United States there is a greater interest in investments in southern timber and timberlands than ever before. The uncertainty associated with these changes has been aggravated by the current lack of stability in the solid wood product and financial markets.

One result of these changes and the current uncertainty is an increasing interest in the analytical tools available to examine investments. The purpose of this paper is to review the economic principles relevant to forestry investments and propose some considerations for the application of these principles. The economic principles which will constitute the core of this effort are the principle of wealth maximization; the identification of appropriate criteria and associated rules for analysis; the analytical conditions which must be met for the criteria calculated to be valid; and the limitations of the economic analysis of forestry investments.

Because it is a review, this paper owes its existence in the form of an intellectual debt to a number of economists and foresters. These include Irving Fisher (1907, 1923, 1930) for the foundations he created by his work on the economic theory of interest and capital. John Green (1971) for his consolidation and exposition of the principles of consumer choice. Jack Hirshleifer (1970) for his refinement of investment theory including a rigorous incorporation of uncertainty. Martin Faustmann (1849; Linnard, & Gane, 1968) for his initial effort to use the rate of interest as a price to equate consumption claims at different points in time in a forestry problem. And Mason Gaffney (1960) for his thorough examination of issues related to rotation length and growing stock efficiency in terms of economic principles.

Because of the importance of prices in the analysis of all investments a review of their role and meaning in society is important to an understanding their place in the economics of forestry. Friedman (1962) discusses the role of prices in solving the five(5) basic problems which must be handled by all societies. These are the "fixing of standards" or identifying what consumers or society wants. "Organizing production" or the combining of resources to satisfy the wants of consumers. "Distributing the product" or identifying who is going to consume the results of the production process. "Providing for economic maintenance and progress", which is to say continuing to satisfy the demands of society through time and the anticipation of future demands. And last "adjusting consumption to production over short periods", which is the same as rationing. In this context it is important to recognize markets and their associated prices as a society's collective expression of its tastes, the availability of resources, the possibilities for production and the value of today versus tomorrow. Further, markets and market prices serve to encourage individuals to utilize resources in ways consistent with the values set by society (Friedman, 1981).

1And the comments and suggestions offered by reviewers J.E. Hotvedt, Louisiana State University and S.T. Lowery, Washington and Lee University.
One way to illustrate the interaction between prices and consumer preferences is illustrated in Figure 1. In this figure the economy consists of two goods, A and B, the quantities of which are represented by distances along the axes labeled $y_a$ and $y_b$. The preferences of an individual in this example are represented by the indifference curves $U$, $U'$, $U''$, and $U'''$. In the absence of markets this individual is limited to consuming the initial endowment $Y(y_a, y_b)$. If the conditions are expanded to allow individual exchanges through a market which is represented by the area O, M, M. This area is generally referred to as the market opportunity set and represents the combinations of A and B which are attainable through exchange from initial point $Y(y_a, y_b)$. Prices in this, two good, market are defined by the slope of the line MM, and represent the limit of combinations of A and B attainable by this individual through exchange from $Y(y_a, y_b)$.

Price is usually expressed in money terms but in this example to avoid the use of money have one of the two real goods, say A, serve as the monetary unit or numeraire. In this case then the price would be 0.5 A which is to say that 1/2 unit of A exchanges for 1 unit of B or if B were to serve as the monetary unit then the price would be 2 B. Both of which correspond to the slope of MM, which is minus two(-2).

If A is to serve as the monetary unit, then the wealth of this individual is represented by the intersection of MM with the A axis or $W/A$. This is the measure of the total stock of tangible and intangible goods belonging to this individual which have market value (Bannock, et al., 1972). Note that this is a slight departure from the form usually shown in textbooks. The point $Y(y_a, y_b)$ is usually called an income or budget constraint rather than a wealth constraint. This difference (wealth is a stock, income a flow) is not important in this example of timeless choice, but later in the situation of choice over time the corresponding constraint will be shown to be wealth rather than income.

Note also in Figure 1 the illustration of how the individual is encouraged to utilize resources in a manner consistent with the values set by society through the market and expressed by price. The encouragement is achieved through the quality that achieves the highest state of preference for the individual which is defined as the marginal rate of exchange equal to the marginal rate of substitution (the slope of market price line = the slope of indifference curve).

Figure 2 is identical to Figure 1 except that it has been expanded to include the endowment, preferences, and exchange opportunities for an individual making choices of time over time. This has been done by making the objects of choice consumption claims in two separate time periods as represented by $C_0$ and $C_1$. In this case as in the previous one the individual is limited to the consumption of $y_{00}$ units of consumption in period 0 and $y_{01}$ units of consumption in period 1 in the absence of a market. The market for exchanges over time is represented by the opportunity set O, M, M, as in the previous example. The price of intertemporal exchanges is represented by the slope of the line M, M as in the previous example of a single time period.

Instead of quoting the price of a unit of consumption one time period from now in terms of current consumption the usual practice is to say that a unit of
FIGURE 1: THE ENDOWMENT, PREFERENCES, AND EXCHANGE OPPORTUNITIES
OF AN INDIVIDUAL.
FIGURE 2: THE ENDOWMENT, PREFERENCES, AND EXCHANGE OPPORTUNITIES OF AN INDIVIDUAL OVER TIME.
consumption today exchanges for \((1 + i)\) units of consumption one period from now. And \(i\) is expressed as a rate of interest. So in this example instead of expressing the price as \(1/2\) unit of \(C_0\) the price is expressed as 100%.

This use of interest as an expression of the ratio of exchange between present and future claims to consumption allows the summing of consumption claims in different time periods to an equivalent title to consumption in a single period. This is illustrated by the intersection of \(XY\) with the \(C_0\) axis of \(W/P_0\). Which in turn represents the equivalent consumption in period 0 of \(yC_0\) and \(yC_1\).

Figure 2 also illustrates the difficulty in using income as the appropriate consumption constraint. The usual definition of income is that it represents the amount that could be consumed in any single period without impairing future consumption (Bannock, et. al., 1972). However, this definition leads to difficulty in situations where the opportunity exists for exchanges between time periods because any current consumption impairs future consumption. Therefore the appropriate constraint on consumption is wealth, the stock, and not income, the flow.

The importance of this in forestry investments is illustrated by Figure 3 which is similar to Figure 2 except that production possibilities have been added and are represented by the line PP. Line PP represents the combination of consumption claims in periods 0 and 1 available to the individual through productive transformations. The area \(O, P, P,\) is generally referred to as the production opportunity set. The individual facing the opportunities described in Figure 3 would be expected to transform consumption claims in period 0 to consumption claims in period 1 until point \(P^*\) is reached at which point the wealth of the individual is maximized. This is represented by \(W^*/C_1\) on the \(C_0\) axis. The condition of point \(P^*\) is one of equivalence between the marginal rate of transformation on the boundary of the production opportunity set and the marginal rate of exchange on the boundary of the expanded market opportunity set \((OM'M')\). Further the individual would be expected to engage in exchanges along the boundary of the expanded market opportunity set, \(M'M'\), until a preferred set of consumption claims was reached which is represented by \(C^*(C^*C_0, C^*C_1)\). At this point the marginal rate of substitution along the indifference curve is equal to the marginal rate of exchange on the boundary of the market opportunity set.

There are two(2) key points to be drawn from this theoretical examination. The first is that the optimum level of productive transformation or investment is the condition that maximizes the wealth of the individual and is a stock and not necessarily the flow of income. Secondly the demonstration of the Separation Theorem which asserts that the individual finds an overall optimum by a two(2) stage process. First maximizing wealth through movement along the boundary of the production possibility set. Second achieving a preferred consumption set through exchanges along the boundary of the market opportunity set (Hirshleifer, 1970).

INVESTMENT CHOICE

In principle the economics of investment choice are concerned with two basic questions. First what investment opportunities should be undertaken? And second how are the necessary inputs to be obtained taking account of market opportunities? In this context it is important to distinguish between
FIGURE 3: THE ENDOWMENT, PREFERENCES, EXCHANGE AND PRODUCTION OPPORTUNITIES OF AN INDIVIDUAL OVER TIME.
investment criteria and their associated rules. A criterion is the mathematical formula computed on changes in consumption claims. While a rule indicates the acceptability of an investment directing a comparison between the computed criterion and some other standard.

The criteria most often used by economists in the analysis of investments are present value or present worth. These criteria are defined as the value in terms of present consumption of a dated sequence of consumption claims and are a measure of wealth. There are four general versions of present value criteria, all essentially equivalent, to which rules are applied in the analysis of investments.

The first of these endowed wealth is represented by \( W/C_0 \) in Figure 3 and is the present value of the endowment sequence represented by \( Y \). And may be determined by the generalized formula:

\[
W_o^Y = \sum_{j=0}^{n} \left( \sum_{i=1}^{m} \bar{P}_{ij} Y_{ij} \right) (1 + \bar{r}_j)^{-1}
\]

(1)

when:

\( W_o^Y \) = endowed wealth

\( \sum_{i=1}^{n} \bar{P}_{ij} Y_{ij} \) = sum of good \( Y_i \) times its price \( \bar{P}_i \) in period \( j \).

\( (1 + \bar{r}_j)^{-1} \) = the reciprocal of the product of intertemporal prices \( (1 + r) \) for period \( o \) to \( j \).

The second, attained wealth is represented by \( W/C_0 \) in Figure 3 and is the present value of the sequence of consumption claims represented by \( P^k \). And may be determined by the generalized formula:

\[
W_o^P = \sum_{j=0}^{n} \left( \sum_{i=1}^{m} \bar{P}_{ij} P_{ij} \right) (1 + \bar{r}_j)^{-1}
\]

(2)

when:

\( W_o^P \) = attained wealth

\( \sum_{i=1}^{n} \bar{P}_{ij} P_{ij} \) = sum of good \( P_i \) times its price \( \bar{P}_i \) in period \( j \)

resulting from the total investment ensemble.

\( (1 + \bar{r}_j)^{-1} \) = the reciprocal of the product of intertemporal prices \( (1 + r) \) for periods \( o \) to \( j \).
The third, wealth gain is represented by the difference between \( \frac{W}{C_0} \) and \( \frac{WY}{C_0} \) in Figure 3 and is the difference between the endowed wealth and attained wealth of the adopted investment ensemble represented by \( P^k \). Wealth gain may be represented by the generalized formula:

\[
W^q = W^p - W^y
\]  

when:

\[
W^q = \text{wealth gain} \\
W^p = \text{attained wealth} \\
W^y = \text{endowed wealth}
\]

The fourth present value or worth criterion is usually referred to as project present value and represents the changes in consumption claims associated with an incremental movement along the boundary PP in Figure 3. The generalized formula for project present value may be represented by:

\[
W^\Delta q = \sum_{m} \left( \sum_{n} P_{ij} \Delta q_{ij} \right) (1 + r_j)^{-1} \]  

when:

\[
W^\Delta q = \text{project present value} \\
\sum_{n} P_{ij} \Delta q_{ij} = \text{sum of the changes in quantity (}\Delta q_{i}\text{) of good } i \text{ times its prices (}\bar{P}_{i}\text{) in period } j \text{ for a given investment project,} \\
(1 + r_j)^{-1} = \text{the reciprocal of the product of intertemporal prices (}\bar{P} \text{) for periods } o \text{ to } j.
\]

The rules, which you might infer from Figure 3, are to maximize attained wealth and wealth gain, and to accept an investment project as long as the project present value is positive.

The other common class of criteria used to evaluate investments are labeled as the rate of return, rate of return over cost, marginal efficiency of capital, marginal efficiency of investment, or internal rate of return. The problems and characteristics associated with these criteria have been discussed by numerous authors (Hirshleifer, 1970; Lewis, 1976). This paper will not discuss these in detail except to mention the fundamental weakness of these criteria which is their inability to define the appropriate scale of investment. This results from the basic nature of the criteria which are measures of the rate of change in value over time and provides no information on the amount of value involved in absolute terms.

The basic principle of investment choice is that consumers will achieve a preferred position by a two stage process involving first the maximization of wealth through productive transformations followed by intertemporal exchanges.
to achieve a preferred mix of consumption claims over time. The criteria which have been developed to evaluate investment opportunities have recognized these principles and are based on the measurement of the stock of wealth created through the investment process.

One of the theses of this paper is that the current practice of basing the estimate of investment criteria directly on cash flows generally leads to biased estimates of the present value of forestry investments. This is particularly true in the south at the present time because of the active markets in the region for forest land, and immature as well as mature timber. The argument for this statement is as follows and concerns the recognition of volume and value created through the physical growth of forests. The standard practice is to recognize this growth at the time of harvest or sale in terms of cash flow created. In reality the potential opportunity for consumption was created continuously during the period since investment. The failure to recognize the increment at the time of creation means that the value of growth is discounted below the level necessary to have equivalence with current consumption.

The cumulative effect of basing estimates of present value or rate of return directly on cash flows is to bias the estimates of these criteria substantially below their actual values.

Up to now this paper has dealt with the economic principles for forestry investments in a world of certainty. However, forestry investments like all other investments must be made in an uncertain world.

The economic theory of consumer choice under uncertainty has split into two branches. The first of these reduces the determinants for selection to the expected object of choice and the variance of the distribution of possible outcomes. Generally this is called the mean variance approach (Green, 1971) or the mean and standard deviation as objects of choice approach (Hirshleifer, 1970). In order for the mean and variance of an object of choice to function as the sole determinants of choice two restrictive assumptions must be accepted. The first is that consumption titles must be normally distributed. The second is the basic requirement, that for the mean and variance to adequately function as the determinants of choice the individuals preferences must be such that as wealth is increased the willingness to accept uncertainty in asset holdings is decreased (Green, 1971).

The second framework for choice under uncertainty is called "state preference theory" and will be the basis for the following discussion of principles for investment choice in forestry (Hirshleifer, 1970; Lewis, 1976). The objects of choice in state preference theory are contingent titles to consumption. These titles are contingent upon the state of the world. An example of a contingent title to consumption would be a win ticket on a two horse race. The contingent title is the pay out of the ticket which only pays if one of the horses wins, but not if the other horse comes in first.

The second requirement of state preference theory is that there is no uncertainty as to whether the contingent title to consumption will be redeemed. All uncertainty is limited to what state will occur and none is associated with the availability of the consumptive claim.
The central principle of state preference theory is that the preferences of individuals for contingent claims to consumption are reflected in their indifference curves exactly parallel to the indifference curves for individual under the assumption of certainty. Further the collective preferences of all the participants are aggregated in market prices for contingent consumption claims. And in the case of investment opportunities are reflected in the interest or discount rate at which these claims are exchanged.

This means that the appropriate criteria for the evaluation of forestry investments is one of the forms of present certainty equivalent value (Hirshleifer, 1970; Lewis, 1976) based on the discount rate for the appropriate risk class. Lewis (1976) proposed that this rate be based on the real marginal annual rate of return earned by the equity owner of forest products firms, with a major portion of their assets in forest land and timber inventories, and traded on the New York Stock Exchange.

CONDITIONS

Based on these principles an analysis of forestry investments must meet two important conditions with regard to the prices incorporated in the analysis. The first of these is that all prices must be "real" prices in the sense that they reflect the true impact of exchanges reflected in the analysis. This means first, that all costs and benefits must reflect the full price including indirect costs and benefits. Second, prices should be incorporated as after tax prices because of the differential tax impact of different types of forestry investments (Lewis, 1976). This is different than the usual practice which is to base the analysis on before tax cash flows and assess the impact of taxes at the end of the analysis. The flaw in this practice is the failure to recognize the tax differentials between different forms of forestry investments internally in the analysis.

The third aspect of the estimation of real prices for forestry investments is perhaps the most important. This is the recognition of real price of intertemporal exchanges. This means recognizing changes in the value of money in all prices used in an analysis as well as in the rate of interest for the class of risk appropriate to the investment.

LIMITATIONS

Up to this point the condition of perfect markets has been a necessary condition. If this condition is relaxed and the principles of consumer choice are applied to investment problems in imperfect markets the separation theorem no longer applies. This is illustrated in Figure 4 under conditions of divergent borrowing and lending rates. The line B*B, represents the boundary of the market opportunity set under conditions where the consumer is a net borrower. Line L*L, is the boundary of the market opportunity set where the consumer is a net lender. It follows then, that the opportunity set available to this consumer, who is starting at Y, and has both production and exchange opportunities consists of the set bounded by B, B*, L*, L. Note that the optimum point of production is not uniquely determined by price alone. But is influenced by the preferences of the consumer. In this case, the relative preference for consumption now or in the next period. A detailed proof of this is given by Hirshleifer (1958).
Because the separation theorem does not hold the decision regarding productive investments is not completely independent of the preferences of the decision maker. The best that can be expected of the criteria of investment analysis is to define "simple" or "opportunity dominant" investment opportunities (Hirshleifer, 1970; Lewis, 1976). This means it is impossible to define a uniquely best or optimum investment opportunity independent of individual preferences.

CONCLUSION

The important economic principles identified and reviewed in this paper are first that the appropriate criteria for the analysis of forestry investments are "present certainty equivalent value" of attained wealth, wealth gain, and project value. These criteria are all estimates of wealth as a stock and not income which is a flow. Further the argument is presented that basing the estimation of present certainty equivalent value criteria solely on cash flows leads to biased estimates of the criteria.

Second, real prices which are consistent with the theoretical algorithms of intertemporal consumer choice are the appropriate prices for the analysis of forestry investments. These prices must be expressed in units of constant value and recognize the impact of taxes, both income and valorem.

Third, because of the failure of the separation theorem to hold under conditions of imperfect markets it is not possible to identify uniquely optimum investment ensembles which are independent of the preferences of the decision maker.2

2For a more detailed discussion and mathematical derivation of the material covered in this paper see Hirshleifer (1970) or Chapters 2 and 4 of Lewis (1976).


