A Decision Model For The Estate Management Problem

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Abstract
The legal notices of any daily newspaper attest to a problem that confronts almost every member of society, the problem of transferring property between generations at death. Contrary to common belief, the division of property among one's heirs is not predetermined or imposed, but can be significantly influenced with proper planning. Serious economic losses and family arguments can be avoided with forward planning. However, planning for the transfer of property between generations requires the systematic evaluation of how adequately alternative legal and financial tools satisfy specified estate management goals.

Disciplines
Business Administration, Management, and Operations | Property Law and Real Estate | Real Estate | Taxation-Federal Estate and Gift
A DECISION MODEL FOR THE ESTATE MANAGEMENT PROBLEM

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ABSTRACT

Estate management planning involves the development of a comprehensive plan to (a) insure economic management of the estate property during and after the lifetime of the owner, and (b) create the desired legal consequences in the disposition of the property. For adequate analysis, both the time and uncertainty dimensions of the estate management problem must be considered. This paper develops a dynamic decision model that can be used to evaluate how well alternative legal and financial tools satisfy specified estate management goals. This conceptual model is transformed into a stochastic, multi-stage simulation model and empirical results for a case estate are summarized.
I. INTRODUCTION

The legal notices of any daily newspaper attest to a problem that confronts almost every member of society, the problem of transferring property between generations at death. Contrary to common belief, the division of property among one's heirs is not predetermined or imposed, but can be significantly influenced with proper planning. Serious economic losses and family arguments can be avoided with forward planning. However, planning for the transfer of property between generations requires the systematic evaluation of how adequately alternative legal and financial tools satisfy specified estate management goals.

The purpose of this paper is to develop a decision model that can be used in the evaluation of legal and financial tools for estate management. In Section II the concepts of estate management will be developed. Section III presents a conceptual model of the estate management problem in equation form. The transformation of this conceptual model into a stochastic multi-stage simulation model is discussed in Section IV. Section V presents illustrative empirical results generated by the simulation model. Finally, Section VI presents a summary of the implications of additional analyses and the potential for using the model for individualized estate management planning.

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II. CONCEPTS OF ESTATE MANAGEMENT

One of the major goals of any estate management plan is to transfer the largest amount of property from the parents to the heirs [4, 11, 14, 15, 16, 17]. To satisfy this goal, the optimal plan must minimize the transfer losses that occur because of death and income tax obligations, management and legal fees, and liquidation of assets at less than market value. A plan to satisfy this goal would be easily determined if the date of death was known with certainty. However, the date of death is uncertain in nature, so plans must be made for the production and allocation of income in case death does not occur at the expected time. These creation decisions will change the asset composition and size of the estate, thus requiring a new plan to transfer the property to the heirs. For example, changes in the parent's will and the amount of property given to various heirs may be required if estate size has been increased. For the young estate owner, the acquisition of long term debt to purchase business assets may not only require adjustments in transfer plans, but also the acquisition of additional credit life insurance. Conversely, investing earnings from a large estate in marketable securities rather than business assets that must be liquidated at a loss may result in a larger amount of property that can be transferred to the heirs. Thus, estate management planning requires the simultaneous analysis of estate creation and estate transfer decisions in an environment where time and uncertainty are considered explicitly.
A number of alternative methods can be used to create and transfer an estate. Transfer decisions include the choice among alternative types of wills, types of property ownership, sales agreements, gift arrangements, trusts and business organizations. Not only must specific transfer methods be chosen, but the type and amount of property to be transferred and the recipient of this property must also be determined. In general, creation decisions involve selecting among various consumption and investment alternatives. If the estate includes a family firm, a number of production and investment decisions related to the family business must also be specified. Each set of creation and transfer decisions will result in a different level of satisfaction of the estate management goal. Consequently, a decision model that specifies the utility resulting from various decisions must be used to evaluate alternative estate management strategies.
III. THE CONCEPTUAL MODEL

The estate management problem can be formulated as a stochastic multi-stage decision problem. The objective is to choose a strategy that will:

Maximize: Expected Value of the Transferred Estate

\[ H = \sum_{m=1}^{f} \theta_m^{k,K} \cdot H_m^{k,K} \quad \text{with } k = 1 \]

Where: Mortality Probabilities

\[
\begin{bmatrix}
\theta_1^{m,0,0} & \theta_0^{m,0,0} \\
\theta_2^{m,0,0} & \theta_1^{m,0,0} \\
\theta_3^{m,0,0} & \theta_2^{m,0,0} \\
\vdots & \vdots \\
\theta_k^{m,0,0} & \theta_{k-1}^{m,0,0}
\end{bmatrix}
\]

\[
\begin{bmatrix}
\theta_1^{m,1,1} & \theta_0^{m,1,1} \\
\theta_2^{m,1,1} & \theta_1^{m,1,1} \\
\theta_3^{m,1,1} & \theta_2^{m,1,1} \\
\vdots & \vdots \\
\theta_k^{m,1,1} & \theta_{k-1}^{m,1,1}
\end{bmatrix}
\]

\[
\begin{bmatrix}
\theta_1^{m,2,2} & \theta_0^{m,2,2} \\
\theta_2^{m,2,2} & \theta_1^{m,2,2} \\
\theta_3^{m,2,2} & \theta_2^{m,2,2} \\
\vdots & \vdots \\
\theta_k^{m,2,2} & \theta_{k-1}^{m,2,2}
\end{bmatrix}
\]

\[
\begin{bmatrix}
\theta_1^{m,3,3} & \theta_0^{m,3,3} \\
\theta_2^{m,3,3} & \theta_1^{m,3,3} \\
\theta_3^{m,3,3} & \theta_2^{m,3,3} \\
\vdots & \vdots \\
\theta_k^{m,3,3} & \theta_{k-1}^{m,3,3}
\end{bmatrix}
\]

\[
\begin{bmatrix}
\theta_1^{m,4,4} & \theta_0^{m,4,4} \\
\theta_2^{m,4,4} & \theta_1^{m,4,4} \\
\theta_3^{m,4,4} & \theta_2^{m,4,4} \\
\vdots & \vdots \\
\theta_k^{m,4,4} & \theta_{k-1}^{m,4,4}
\end{bmatrix}
\]

\[
\begin{bmatrix}
\theta_1^{m,K,K} & \theta_0^{m,K,K} \\
\theta_2^{m,K,K} & \theta_1^{m,K,K} \\
\theta_3^{m,K,K} & \theta_2^{m,K,K} \\
\vdots & \vdots \\
\theta_k^{m,K,K} & \theta_{k-1}^{m,K,K}
\end{bmatrix}
\]

(expected value of the transferred estate for each mortality)

(probability of mortality)

(probability of death in k)

(probability of mortality m in k)
Where: Present Value of the Transferred Estate for Each Mortality

\[
H_{1,K}^m = \sum_{b=1}^{c} \sum_{h=1}^{z} \sum_{j=1}^{z} \delta_{j1} (G_{hj1}^b + W_{hj1}^b - C_{hj1}^b) + H_{2,K}^m
\]

\[
H_{2,K}^m = \sum_{b=1}^{c} \sum_{h=1}^{z} \sum_{j=1}^{z} \delta_{j2} (G_{hj2}^b + W_{hj2}^b - C_{hj2}^b) + H_{3,K}^m
\]

\[
\vdots
\]

\[
H_{k-1,K}^m = \sum_{b=1}^{c} \sum_{h=1}^{z} \sum_{j=1}^{z} \delta_{jk} (G_{hjk}^b + W_{hjk}^b - C_{hjk}^b) + H_{k+1,K}^m
\]

\[
H_{k,K}^m = \sum_{b=1}^{c} \sum_{h=1}^{z} \sum_{j=1}^{z} \delta_{jk} (G_{hjk}^b + W_{hjk}^b - C_{hjk}^b)
\]

(present value of transferred estate for each mortality from k to K)

(gift transfers in k)

(will transfers in k)

(total transfer costs in k)

(present value of transferred estate for each mortality from k+1 to K)

Where: Additivity Condition

\[
\sum_{m=1}^{h} \sum_{k=1}^{K} \Theta_{m,k,K}^m = 1
\]

(sum of all mortality probabilities equal to 1)
Where: **Probability of Death**

\[
\Pi_k^d = \left[ 1 - \frac{S_{p=h}^{(T_k)}}{S_{p=h}^{(T)}} \right] \cdot \left[ 1 - \frac{S_{p=w}^{(T_k)}}{S_{p=w}^{(T)}} \right] \quad \text{for } d=1, \ldots, 4
\]

\[
\Pi_k^d = \left[ 1 - \frac{S_{p=h}^{(T_k)}}{S_{p=h}^{(T)}} \right] \quad \text{for } d=5, 6
\]

\[
\Pi_k^d = \left[ 1 - \frac{S_{p=w}^{(T_k)}}{S_{p=w}^{(T)}} \right] \quad \text{for } d=7, 8
\]

(5) Probability of Death

Where: **Survival Function**

\[
S_{p}^{(T')} = \Delta_p^{T}
\]

(Makeham's law of mortality)

Subject to: **Gift Transfer Capacity**

\[
\sum_{b=1}^{c} \left( \sum_{h=1}^{z} C_{hjk} - \nu_{jk} \right) \leq A_{jk} - \lambda_{jk}
\]

(gift (net (security transfers) value)

Where: **Net Value of Estate Assets**

\[
A_{jk} = \sum_{j=1}^{z} \left[ A_{jk-1} - \sum_{b=1}^{c} \sum_{h=1}^{z} (C_{hjk-1} + \nu_{jk-1}) \right] + C_{hjk-1} + \omega_{jk} - D_jk + \sum_{g=1}^{e} (O_{gk} - N_{gk})
\]

(transfer cost in previous period)

(estate value in previous period)

(gift transfers in previous period)

(will transfers in previous period)

(asset (depreciation) (principal (new debt) (new PURCHASE) payments) debt)
Where: **Transfer Costs**

\[
(11) \quad \sum_{b=1}^{c} \sum_{h=1}^{z} C_{hjk}^b = \sum_{b=1}^{c} \sum_{h=1}^{z} (c_{hjk}^b g_{hjk}^b + g_{hjk}^b w_{hjk}^b) + \kappa_{jk} T_{jk}
\]

(transfer cost) \hspace{1cm} (gift tax) \hspace{1cm} (estate and inheritance tax) \hspace{1cm} (administrative and management costs)

Where: **Total Transfers**

\[
(12) \quad T_{jk} = T_{jk-1} + \sum_{b=1}^{c} \sum_{h=1}^{z} (G_{hjk}^b + w_{hjk}^b)
\]

(total transfers) \hspace{1cm} (total transfers in previous period)

Subject to: **Limits on Will Transfers**

\[
(13) \quad w_{hjk}^b \leq x_{hjk}^b
\]

(will transfers) \hspace{1cm} (legal and personal constraints)

Subject to: **Creation (Growth) Capacity**

\[
(14) \quad \sum_{j=1}^{2} \omega_{jk}^j T_{jk} \leq F_k
\]

(asset purchases) \hspace{1cm} (investable funds)
Where: Investable Funds

\[ P_k = \sum_{i=1}^{z} \phi_{ik} Y_{ik} + \sum_{g=1}^{e} N_{gk} - \sum_{j=1}^{z} (\xi_{jk} A_{jk} + \xi_{jk} P_{jk}) \]

\[ + \sum_{g=1}^{e} \left( 0_{gk} + \varepsilon_{gk} M_{gk} \right) - L_k - y_k \]

Subject to: Borrowing Capacity

\[ \sum_{g=1}^{e} N_{gk} \leq \sum_{j=1}^{z} \lambda_{jk} A_{jk} - \sum_{g=1}^{e} M_{gk} \]

Subject to: Non-negativity Condition

\[ c_{b h j k}, w_{b h j k}, r_{j k}, n_{g k}, y_{i k}, p_{j k} \geq 0 \]

Subject to: Integer Condition

\[ I_{j k}, P_{j k} \quad \text{integers} \]

Where:

Subscripts and Superscripts

\[ m = \text{the mortality, } m=1, \ldots, f; \]
\[ k = \text{the time period, } k=1, \ldots, K; \]
\[ d = \text{the type of death, } d=1, \ldots, 8; \]
\[ b = \text{the recipient of the assets or the heir, } b=1, \ldots, c; \]
\[ h = \text{the type of gift or will transfer method, } h=1, \ldots, z; \]
j = the type of asset, j = 1, ..., z;
p = the parent where h denotes husband and w denotes wife;
g = the type of debt, g = 1, ..., e;
i = the type of output, i = 1, ..., z;

Decision Variables:

\[ G_{hjk}^b \] = the dollar amount of asset j transferred to heir b by gift transfer method h in period k;
\[ W_{hjk}^b \] = the dollar amount of asset j transferred to heir b by will transfer method h in period k;
\[ I_{jk} \] = the dollar amount of asset j purchased by the parents in period k;
\[ N_{gk} \] = the amount of borrowed funds of type g acquired in period k;
\[ Y_{ik} \] = the amount of output i produced by the firm in period k;
\[ P_{jk} \] = the amount of annual purchased or rented input of type j acquired in period k.

State Variables:

\[ H \] = the expected present value of the estate transferred to the heirs during the planning horizon;
\[ H_{m,k}^m \] = the present value of the transferred estate for each mortality type m from period k through period K;
\[ C_{hjk}^b \] = the total transfer costs incurred when gift or will transfer method h is used to transfer asset type j to heir b in period k;
\[ A_{jk} \] = the net estate value of asset type j in period k;
\[ D_{jk} \] = the dollar amount of depreciation of asset type j in period k;
\(0_{gk}\) = the dollar amount of principal payments on debt of type \(g\) in period \(k\);

\(T_{jk}\) = the total amount of asset type \(j\) transferred to the heirs by period \(k\);

\(F_k\) = the total funds available in period \(k\) for reinvestment in firm or non-firm assets;

\(L_k\) = the amount of income tax payable in period \(k\);

\(M_{gk}\) = the amount of indebtedness of type \(g\) in period \(k\);

**Parameters**

\(\Omega_{k,K}\) = the probability of the death sequence or mortality \(m\) occurring from period \(k\) through period \(K\);

\(\Pi_{d,k}\) = the probability of death type \(d\) occurring in period \(k\);

\(\delta_{jk}\) = the discount factor applicable to asset type \(j\) in period \(k\);

\(T_k\) = the age of the parent in period \(k\);

\(T'\) = the age of the parent at the beginning of the planning horizon;

\(\Delta\) = a mortality parameter (specified by Makeham's law of mortality);

\(\rho\) = a mortality parameter (specified by mortality tables);

\(\omega\) = a mortality parameter (specified by Makeham's law of mortality);

\(\mu_{jk}\) = the security level of asset type \(j\) that must remain in the estate in period \(k\);

\(\omega_{jk}\) = the purchase price of asset type \(j\) in period \(k\);

\(\delta_{hk}\) = the gift tax rates if gift transfer method \(h\) is used to transfer asset type \(j\) to heir \(b\) in period \(k\);
Salient Features of the Model

The Objective Function

The objective function, equation (1) of the conceptual model, identifies the decision rules that are used to evaluate various estate management strategies. The goal is to choose a strategy which will maximize the weighted average of the present value of the estate transferred to the heirs for each environmental state (mortality). The weights are
specified by equation (2) as the probability of the occurrence of each mortality (m) during the planning horizon. Thus, we desire to obtain the Bayes strategy for *a priori* mortality probabilities.

A mortality is defined as a particular sequence of life and death events during the planning horizon. As indicated by equation (2), the probability of each mortality is calculated as the probability of a specific life or death event in each period times the probability of a sequence of life and death events during the previous periods. The occurrence of a life or death event in any period is obviously dependent upon whether or not both parents are living at the beginning of the period. If the parents are both alive, four death events can occur in the period (husband die and wife live, husband live and wife die, both die and both live). The probabilities for these four events are defined by equation (5). If the husband or wife has died previously, then the surviving spouse can either live or die in any period. Equations (6) and (7) define the probabilities of the death events for the surviving husband and wife, respectively.

The probability of each type of death event is also dependent on the age of the parents at the beginning of the planning horizon and the number of periods of the planning horizon that have elapsed. The impact of age and time is incorporated in the probabilities of death by the survival function of equation (8)[12]. Thus, each weight or mortality probability for each period is a compound probability that is dependent on the sequence of deaths in the previous period, the initial age of the parents and the number of periods that have elapsed since the beginning of the planning horizon.
The recursive set of equations specified in (3) defines the utility or response variable used in the objective function. As indicated by the first recursive equation of (3), a response value is calculated as the sum of the gift and will transfers minus transfer costs in the first period plus the present value of the transferred estate from the second period to the end of the planning horizon. However, the last term of this equation is defined by the second recursive equation as the gift and will transfers minus transfer costs in the second period plus the present value of the transferred estate from the third period to the end of the planning horizon. In like fashion, the successive equations of (3) define the transferred estate value from the beginning of each successive period to the end of the planning horizon for each mortality.

The specification of this utility proxy for the estate management problem involved many considerations. In reality, two utility functions, both of them multi-dimensional, are involved in estate management planning. The parent's utility can be specified as a function of the value of the estate transferred to the heirs, a security level of assets, and the ability to direct the distribution of the property. Similarly, the utility function of the heirs can be specified as a function of the same variables. However, the specification of multi-dimensional utility functions is extremely complex and interpersonal comparisons of utility have a questionable theoretical basis at best. Since the parents have initial control of the property, their utility function exclusively is used in the analysis. Utility is assumed to be a linear function of the present value of the net estate transferred to the heirs during the planning horizon. This specification of the utility function is a simple extension of the Fisher criterion of maximizing the purchasing power of a bundle of investments. [9,10]. However, this purchasing power is not measured in terms of withdrawals for direct consumption by the parents, but in terms of withdrawals for transfer to the heirs. The discount rate is assumed to be equal to the borrowing
rate of interest. Thus, the only difference between our criterion and that used in most investment analyses is the inclusion of the event of death and the resulting capital transfers in the planning horizon.

The Constraints

The constraints on estate creation and transfer are specified by inequalities (9), (13), (14), (16), (17), and (18). The amount of any particular class of assets that can be transferred by gift in any period $k$ is restricted by inequality (9) to the net estate value of that asset class minus a security level. The security level is specified by the parents as the amount of assets that must remain in the estate to provide an adequate standard of living for them during their retirement years. Equation (10) defines the net estate value in any period $k$ as the net estate value in the previous period less gift and will transfers and transfer costs in the previous period plus asset purchases and principal payments in the current period less depreciation and new borrowing in the current period.

The costs that are incurred when a particular transfer plan is implemented are defined by equation (11) as the sum of the gift and estate tax liabilities incurred when assets are transferred by a particular method to a particular heir, plus the administrative and management costs on all assets transferred since the beginning of the planning horizon. The cumulative value of all transfers is defined by equation (12) as the total transfers in the current period. The limitations on these will transfers imposed by the state laws of descent and personal constraints on bequests are specified by inequality (13).

As indicated by equation (10), asset purchases increase the size of the estate that can be transferred; but estate creation or asset purchases
in any period is limited by the amount of available investable funds as indicated by inequality (14). Investable funds are defined by equation (15) as the sum of gross revenue and new borrowings minus cash outlays to maintain and repair estate assets, acquire purchased inputs, repay principal on the non-equity capital, pay interest on total borrowed funds, pay income taxes, and satisfy family consumption. The amount of new non-equity funds that can be borrowed is limited by the collateral requirements of lending institutions which, as indicated in inequality (16), is usually based on the net worth of the firm or estate in the current period less current borrowings.

IV. THE EMPIRICAL MODEL

The decision theoretic conceptual model was transformed into a stochastic multi-stage simulation model for empirical analysis. The model utilizes a modified Monte Carlo search procedure to investigate the alternative values of the decision space. For the empirical test, the model was applied to the estate management problem of the Midwest farmer. Consequently, the decision space is comprised of alternative methods of creating and transferring a farm estate which includes farm business assets and non-farm assets.

Certain characteristics of the estate creation-transfer process make it difficult to utilize traditional optimizing procedures to search the decision space. First, a number of the decision alternatives are mutually exclusive or conditionally complementary, and thus each alternative cannot be evaluated independently. In addition, most of the tax, legal and production relationships are non-linear, and the investment alternatives are restricted to integer values. Finally, the stochastic element of death of the parents is an essential element of the estate management problem.
Although it is possible to conceptualize this problem in a discrete stochastic programming or a dynamic programming framework, obtaining an optimal solution to this problem would be costly, if not impossible \(^7\) [1,2,7]. Therefore, a statistical approximation method is used to search the decision space.

In contrast to the random search process used in traditional statistical approximation or Monte Carlo models, the search procedure used in this study combines the random sampling process with a "hill-climbing" mechanism [3]. The random sampling process is used to select the initial values of the decision variables and an "expansion ratio." Then the "hill-climbing" mechanism is used to incrementally increase the values of the decision variables in the proportion specified by the "expansion ratio" until a constraint is reached [8,13,18,19]. Thus, all final solutions occur on the boundary of the decision space and interior solutions that do not utilize all the available resources are eliminated. This procedure thus concentrates the search in that area of the decision space where a priori information indicates the optimal solution will exist. The result is a higher probability of finding the optimal solution with a given number of observations of the decision variables compared to the random procedure [5,6].

The decision tree of Figure 1 indicates the sequence of decisions made by the simulation model in each stage or year and the impact of these decisions and the stochastic event of death on the structural state and decision alternatives in the following year. The annual specification of a set of production, investment and consumption decisions (a creation plan) and the determination of an ownership policy, a gift policy and the elements of a will for each living parent (a transfer plan) occurs at the beginning of each year (node \(A_{j,k}\), where \(j\) refers to the previous life or death event and \(k\) to the year of the planning horizon). The entire creation plan and the ownership and gift decisions are then implemented (branch \(B_{j,k}\)). Once
the estate size and ownership implications of these decisions have been
determined (node $C_{j,k}$), the different possible life and death events are
assumed to occur and the relevant wills are executed. The execution of the
wills for year 1 occur at nodes $D_{j,1}$, where $D_{1,1}$ indicates that both the
husband and wife live, $D_{2,1}$ that the husband lives and the wife dies, $D_{3,1}$
that the husband dies and wife lives and $D_{4,1}$ that both the husband and
wife die. The results of these executed wills for each death event are
specified at the $E_{j,k}$ nodes. Thus, creation and transfer decisions in the
following year ($k' = k + 1$) are conditional on what mortality has occurred
previously and the impact this mortality has on the asset composition and
ownership structure of the firm.

The value of the property received by the heirs at the end of the
planning horizon for each mortality (each terminal node $E_{j,k}$ where the
terminal year ($k$) is 3 in Figure (1)) is calculated according to equation
(3) as the discounted value of the property transferred to the heirs at
this terminal node plus this value for all previous intraconnected $E_{j,k}$
nodes. The probability of arriving at each terminal $E_{j,k}$ node is calculated
according to the conditional probability statement of equation (2). Thus,
the expected value of the net estate transferred to the heirs (equation (1))
is calculated as the transferred estate value at each terminal node $E_{j,k}$
times the probability of arriving at that node.

V. EMPIRICAL RESULTS

The simulation model was applied to a number of farm family-estate situa-
tions for empirical testing and verification. These situations included
different estate sizes and different ages of the parent(s) for both the wid-
ow(ern) and the husband and wife. Only the results generated for a $385,000
estate owned by a 65 year old husband and his 60 year old wife will be re-
viewed here. The parents have two grown children, a married son who is in-
volved in the farming operation and a married daughter. The size, asset
Figure 1. Decision tree of the estate creation-transfer process.

- Year 3
  - Results of will decisions
  - Execute wills for each life or death event
  - Results of creation, ownership and gift decisions
  - Implement creation, ownership and gift decisions
  - Make creation and transfer decisions
  - Results of will decisions
  - Execute wills for each life or death event
  - Results of creation, ownership and gift decisions
  - Implement creation, ownership and gift decisions
  - Make creation and transfer decisions
  - Results of will decisions
  - Execute wills for each life or death event
  - Results of creation, ownership and gift decisions
  - Implement creation, ownership and gift decisions
  - Make creation and transfer decisions

- Year 2
  - Results of will decisions
  - Execute wills for each life or death event
  - Results of creation, ownership and gift decisions
  - Implement creation, ownership and gift decisions
  - Make creation and transfer decisions
  - Results of will decisions
  - Execute wills for each life or death event
  - Results of creation, ownership and gift decisions
  - Implement creation, ownership and gift decisions
  - Make creation and transfer decisions

- Year 1
  - Results of will decisions
  - Execute wills for each life or death event
  - Results of creation, ownership and gift decisions
  - Implement creation, ownership and gift decisions
  - Make creation and transfer decisions
composition and ownership structure of the estate and farm are summarized in Table 1.

The first two years of best estate management strategy of the fifty investigated is summarized in the decision tree of Figure 2.\(^8\) This decision tree indicates that the creation plans for year 1 include the production of 640 acres of corn, 1292 head of market hogs and the investment of $20,000 in off-farm assets (branch \(B_{1,1}\)). This creation plan generates a 3.64% return and an ending net worth of $482,221. The gift policy involves transferring $14,500 of farm personal property from the wife to the husband, $2,500 from the wife to the children and $8,500 of the jointly held property (owned by the husband and wife in joint tenancy) to the children. Both the husband and wife have "simple" wills in the first year (branches \(D_{2,1}, D_{3,1}\) and \(D_{4,1}\)). If the wife dies in the first year (branch \(D_{2,1}\)), the husband would receive $301,503 ($258,834 + $42,669) of property and the children would receive $85,078 of property under her will. Total transfer costs, including taxes, probate and legal fees, would amount to $48,641. The present value of all property transferred by gift or will to the children in this mortality situation (net of transfer costs) is $44,334. A similar explanation applies to death of the husband only (branch \(D_{3,1}\)). If both parents die in the first year (branch \(D_{4,1}\), the children receive $14,500 of property from the husband, $127,745 from the wife and $258,834 of property that was owned jointly by the husband and wife. The total transfer costs amount to $138,734 and the present value of the property received by the heirs is $255,462.

The second year creation plans are similar for all three previous mortalities (branches \(B_{1,2}, B_{2,2}\) and \(B_{3,2}\)). As in year one, they again include the corn, hog and outside investment enterprises. However, the
Table 1. Size and Composition of the Estate for Two Sixty Year Old Parents With Two Children.

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount, Size of Capacity</th>
<th>Value Owned by Husband</th>
<th>Value Owned by Wife</th>
<th>Value Owned Jointly</th>
<th>Value Owned by Children</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real Estate &amp; Improvements</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm Real Estate</td>
<td>506 acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm Real Estate</td>
<td>140 acres</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sow Main. Fac.</td>
<td>50 sows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sow Farrowing Fac.</td>
<td>50 sows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pig Nursery Fac.</td>
<td>25 litters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pig Finishing Fac.</td>
<td>40 litters</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cattle Finishing Fac.</td>
<td>250 cattle</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Urban Real Estate</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Farm Personal Property</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row-Crop Tillage &amp; Planting Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Power Equipment</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Harvesting Equipment</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Crop &amp; Livestock Inventory</td>
<td></td>
<td>$21,454</td>
<td></td>
<td></td>
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<tr>
<td>Cash</td>
<td></td>
<td>$22,550</td>
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<tr>
<td><strong>Outside Investments</strong></td>
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<td></td>
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<tr>
<td>Checking &amp; Savings Account</td>
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<td></td>
<td>$30,200</td>
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<tr>
<td>Certificates of Deposit</td>
<td></td>
<td></td>
<td>$8,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stocks &amp; Bonds</td>
<td></td>
<td></td>
<td>$18,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home Furnishings &amp; Auto</td>
<td></td>
<td></td>
<td>$4,300</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Insurance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole Life Policy</td>
<td></td>
<td>$1,000</td>
<td></td>
<td></td>
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<tr>
<td><strong>Total Value</strong></td>
<td></td>
<td>$45,004</td>
<td>$88,000</td>
<td>$252,328</td>
<td>$79,956</td>
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<tr>
<td><strong>Total Value-Parents</strong></td>
<td></td>
<td>$385,332</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Total Value-Children</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$79,956</td>
</tr>
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</table>
Figure 2. The Best Strategy For the Case of Two Sixty Year-old Parents with Two Children and a $385,000 Estate.
FOOTNOTES (FIGURE 2)

a/SPDHP indicates the use of a spring plow, disc harrow and plant production system. FPCUP denotes a fall plow, spring field cultivate and plant production system.

b/M denotes the farrowing and finishing of market hogs. WP indicates the farrowing and selling of weaner pigs.

c/Out. Inv. indicates the amount of funds invested in non-farm assets this year.

d/Net worth of the firm at the end of the year.

e/Total asset position of the firm at the end of the year.

f/Percent return on equity capital.

g/Value of the property included in the firm that is owned by the wife, the husband, the wife and husband jointly and by the children.

h/Indicates the individual who will own the new farm personal property, real estate and outside investments acquired during this year.

i/Identifies the type of property that has the highest gift transfer priority.

j/Indicates the amount of property transferred to various beneficiaries. Jnt. denotes a transfer from joint ownership. Hus. denotes the husband. T indicates a trust gift. O denotes an outright gift.

k/Identifies who dies on each death event or M_j,k branch.

l/S indicates a straight will; T denotes a trust will.

m/Indicates the amount of property transferred to each heir by the will.

n/Specifies the accumulated cost of implementing the transfer plans on all interconnected branches back to the first year.

o/Dis. Val. Est. indicates the present value of all property transferred (net of transfer costs) from the parents to the heirs through this year.

p/Applicable only in the case of a simultaneous death of both parents.
deaths in the previous year result in significant differences in the ownership structure of the firm and gift and will policies for each mortality in year two. For example, a total of $56,500 of property is given to the children when both parents are still alive in year two (branch $B_{1,2}$). In contrast, if the husband died in year one, the children only receive $16,500 from the wife in the second year (branch $B_{3,2}$). If both parents live through the first year, then four death events can occur in year two and the transfers and costs that result are summarized on branches $D_{1,2}$, $D_{2,2}$, $D_{3,2}$ and $D_{4,2}$. Thus, the death of both parents in the second year results in $131,929 of transfer costs and a present value of the transferred estate of $254,988.

In contrast, if the wife died in year one and the husband in year two (branch $D_{6,2}$), transfer costs amount to $91,403 and the children would receive property with a present value of $257,920.

In general, the best estate management strategy for two sixty year-old parents includes high return annual creation plans for all six years of the planning horizon. These high returns are generated by expanding the corn, hog and outside investment enterprises. The ownership structure of the firm changes significantly from the first year, when most of the property is owned solely by the wife or jointly by the husband and wife to the last year. By year six, the children own $216,776 of the firm's net worth even if the parents are still alive. Most of this property has been received as gifts from the parents. In addition, the amount of property owned jointly by the husband and wife has been substantially reduced by the sixth year, and the property the husband and wife do hold is solely owned and equally distributed between them.
VI. CONCLUSION

The numerical results presented here along with other applications of the estate management model indicate that dynamic analysis of the interaction between the processes of creation and transfer is necessary for accurate estate management planning. The development of transfer plans to be implemented at death is essential, but if death does not occur at the appointed time, creation plans that include production, investment and consumption decisions must be available to efficiently utilize earnings and available resources. In fact the empirical results of this study indicate that the highest response estate management strategies invariably included creation plans that generate high rates of growth in estate size. Consequently, the uncertainty and time dimensions of the estate management problem can not be ignored.

The analysis of numerous farm family-estate situations has resulted in a number of additional generalizations that are useful to estate planning practitioners. Investment in liquid assets such as stocks and bonds or life insurance as well as business assets is an important component of most of the high response estate management strategies. The non-business investments not only generate a reasonable and relatively riskless return, they also provide liquid funds to compensate heirs not involved in the family business and pay death taxes and estate administration costs. Significant amounts of lifetime gifts are also part of the best estate management strategies. In fact, for the larger estates and older parents, the empirical results indicate that large enough amounts of property are transferred to the heirs as gifts that gift taxes must be paid. Thus, the
traditional rule of thumb that gifts should not exceed the annual exclusion and lifetime exemption may not be applicable to large estates. In addition, a substantial portion of the property transferred as gifts is business property that remains in use within the firm. Thus, the firm can continue to exploit economies of size and capital intensive technologies. In fact, the results suggest that for the family held firm there may be significant advantages to such business organizations as the closed corporation which facilitate the reallocation of property ownership within the firm without changing the size or asset composition of the firm. Finally, the numerical results indicate that the economic benefits (cost savings) of proper estate planning relative to estate size are higher for the small compared to the large estate.

In addition to these estate planning generalizations, the specific numerical information provided to individual estate owners who utilize the decision model has considerable merit. It is important to recognize that estate management plans must be tailored to individual preferences and family characteristics. By including these characteristics and preferences in the model, detailed schedules of production, investment, consumption and transfer decisions and their related benefits and costs can be generated which will enable an estate owner to evaluate the financial and ownership consequences of alternative estate management strategies prior to implementation. In the empirical testing of the model, input data was collected from a farm family in personal interviews and processed at a cost of approximately $150. The results suggested significant but reasonable changes in the estate plans currently used by the family. Thus, this or a similar model appears to have significant potential as an operational tool of an estate management planning service.
Obviously, other estate management goals such as control over the specific distribution of the estate property and income and wealth security for the parents also exist. These goals can be and are included in the specific analyses reported here as indicated in equations (9) and (13) of the conceptual model.

This model includes sufficient detail to accommodate an estate that includes a family firm, but it is also applicable to an estate composed only of interest, dividend, or rental property.

It should be recognized that all of the structural states are conditional on which mortality \( m \) occurs. Because of the confusion that might occur by adding another subscript to an already complicated mathematical formulation, the state of nature subscript is implicit on all structural variables.

Listed in the order of their appearance in the equations.

However, note that the security and directed distribution goals are incorporated in the analysis through constraints (9) and (13).

However, if estate transfers in a given period are actually constrained by this security limit and firm profits are negative in following periods, the estate value could decline below this security level. Thus, there is a possibility that this security constraint will be violated in any period.

Although error-free mixed integer, stochastic and non-linear solution procedures have been developed, they do not appear to be computationally efficient when applied to problems of this complexity; see \([1, 2, 7]\).
Each strategy consists of a set of annual creation plans (what products to produce and resources to acquire) and a set of annual transfer plans (the ownership, gift and will policies) for each possible mortality during a six year planning horizon. Because of space limitations, the entire strategy is not presented in detail.
REFERENCES


