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Commodity Costs and Returns Estimation Handbook

A Report of the AAEA Task Force on Commodity Costs and Returns

July 20, 1998

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CHAPTER 10

ALLOCATING PREPRODUCTIVE COSTS FOR MULTIYEAR ENTERPRISES

INTRODUCTION

Many enterprises require the development of assets that generate production for more than just one year. Perennial crop, tree fruit, nut, vineyard, breeding livestock, and dairy enterprises all produce revenue for multiple years, and each of these enterprise types also involves a period of time during which costs are incurred prior to productive periods. These costs must be accounted for in estimating production costs and returns (CARs) of multiyear enterprises.

This chapter defines terms associated with multiyear enterprises. Major issues associated with crop and livestock enterprises are explored as they pertain to preproductive cost determination and allocation. Alternative allocation methods are discussed emphasizing consistency with economic theory, limitations of the approaches, and proper interpretation of CAR estimates using each approach. The chapter concludes with general recommendations regarding the treatment of preproductive costs, including reporting issues such as format and classification of costs, as well as a discussion of the comparison of CAR estimates for enterprises with different lives. Long-lived assets such as breeding stock, trees, vines, and specialized facilities may have special tax treatment that could affect investment decisions. This discussion avoids these issues because they must be handled on a case-by-case basis.

DEFINITIONS

A **multiyear enterprise** is an enterprise with more than one annual production period. The **preproductive** period for a multiyear crop enterprise begins with the first expense associated with establishing the crop enterprise and ends in the crop year just before the crop yields a substantial percent of its expected mature yield (usually 70-80%). This definition is slightly broader than the definition used by the Internal Revenue Service (IRS), which specifies that "the pre-productive period ends when the plant becomes productive in marketable quantities..." (IRS: 34). For purposes of estimating economic CARs, it is more reasonable to end the preproductive period in the year just prior to the crop attaining a substantial portion of its long-run mature yield. The preproductive period may be equal to or greater than 12 months. For livestock, the preproductive period begins with the birth or purchase of animals to be used for breeding or milking, and ends at the beginning of the production year in which they begin production. For multiyear enterprises, a year is defined as a 12-month period that corresponds with either a calendar year or a production year. A **single-year enterprise** with a **multiyear preproductive period** is an enterprise that has harvestable yield in only one year but requires several years to establish and produce.

Consider a few examples to make the ideas clear. Alfalfa normally has a productive life of 3-4 years after the initial year of planting. Although there is usually some marketable alfalfa in this first year, it is standard to consider this year as one of preproduction with net production costs adjusted for the value of any crop produced, whether it be alfalfa hay or a companion crop such as oats. Dwarf apple trees normally begin yielding some marketable fruit in the fifth year following planting and reach production near mature yield in the seventh year. The trees usually cease having economic yield by the fifteenth year. In developing an annual budget for apples, one could use average yields over years 5-14 and assume that all costs in years 1-4 are preproductive; or, one could use average yields over years 7-14 and assume all net costs (allowing for the apple sales in years 5 and 6) are preproductive costs. Alternatively, one could use individual year-by-year yields for the productive period and create an annuity that has the same present value as the discounted costs over the productive years (5-14 or 7-14). If a dairy cow is purchased at the beginning of her productive life (ready-to-milk), she can be treated as a durable good and handled in a manner similar to equipment, as outlined in Chapter 6, where the difference between purchase price and discounted projected salvage value is amortized over her productive life as an annuity. If she is raised on the farm, it is still probably appropriate to use the going market price for a similar heifer as the initial cost and proceed as if she were purchased.

Enterprise costs that occur during the preproductive period are defined as **preproductive costs**. Preproductive costs include both operating costs and allocated overhead. These costs are estimated in exactly the same manner as enterprise costs for enterprises that are not multiyear. In order for an enterprise to be profitable, these preproductive costs, plus interest on the financial capital tied up in their production, must be recovered during the productive years of a multiyear enterprise. Therefore, the preproductive costs of an enterprise, plus interest, must be allocated as a cost of doing business over the productive years of the enterprise.

Two types of capital (durable) assets are defined with regard to multiyear enterprises. **Enterprise specific capital** is capital that is used only for the given enterprise and whose useful life is tied directly to the life of the enterprise. Enterprise specific capital is purchased during the preproductive period of a multiyear enterprise, and is disposed of or used up at the end of the enterprise's useful life. Acquisition costs of enterprise specific capital should be included as preproductive costs in the years they are acquired and allocated in conjunction with all other preproductive costs to enterprise production cost estimates. Examples of enterprise specific capital include trellis systems or irrigation systems that are constructed during the establishment period and removed when the enterprise is discontinued and trees or rootstock that are planted during the establishment period and removed when the enterprise is discontinued.

Other capital is used (or may be used) for more than a single enterprise and its useful life is not tied directly to the life of single enterprises. This distinction in capital is important in estimating costs for allocated overhead. The overhead costs of whole-farm durable assets are calculated and allocated according to procedures identified in Chapter 6 for both preproduction and production years. Examples of such durable assets include tractors, buildings, and irrigation pumps. Because these capital items are used for multiple enterprises, their annual costs must be allocated based on their proportion of use in each enterprise, as discussed in Chapter 9.

INFLATION ISSUES

Because preproductive costs occur over a period of years, inflation and the distinction between nominal and real interest rates must be considered. As suggested in Chapters 2 and 6, the convention will be to value all CAR streams in nominal values at the end of the current period and view the end of the current period as a base in computing real values for other periods. The convention is also that all CAR flows outside the current period are denominated in real terms relative to the end of the current period and that no inflation or deflation occurs except in the current period. This convention is followed because projected CAR estimates usually use current year nominal data to estimate costs for all previous and future years. In a time line context this can be represented as follows:

$\pi=0$	$\pi=0$	$\pi=0$	$\pi=0$	$\pi=0$	$\pi=\pi_1$	$\pi=0$	$\pi=0$	$\pi=0$	$\pi=0$
$i=r$	$i=r$	$i=r$	$i=r$	$i=r$	$i=i_1$	$i=r$	$i=r$	$i=r$	$i=r$

-5   -4   -3   -2   -1   0   1   2   3   4   5

where π_j is the inflation rate in period j, r is the real interest rate (assumed constant), and i_j is the nominal interest rate in period j. We assume that inflation is constant and equal to zero in all but period 1. Thus we can compute the nominal interest rate in the first period as $i_1 = (1+\pi_1)(1+r)$. The current period ends at date 1 while the third preproductive period begins at date -3. If data on a period other than the current one are in nominal terms for that period, they should be adjusted to real terms for analysis unless there is an explicit desire to use nominal interest rates throughout. Historical CAR data will need to be converted to a real basis for analysis or else nominal interest rates must be used for discounting.

In a projected budget for the current year, the suggested approach is to compute all preproductive costs using current year projected nominal prices. These costs (and any returns) can then be adjusted to the end of the current period using the current nominal interest rate. These preproductive costs are then adjusted back in time to the end of each preproductive period using the current nominal interest rate for the current year and the real interest rate for years prior to the current one. This is similar to the approach suggested in Chapters 2 and 6 with regard to capital expense items that are purchased at the current time and used over several periods in the future. This is appropriate because projected data on costs are usually denoted in current values and that is how they are routinely collected. Returns that occur at the end of the current year should be expressed in nominal terms as of the end of the year because this is the base for CAR estimation. If data on CARs are for the beginning of the current period rather than the month of expenditure or receipt, they should be adjusted to the appropriate point in the period using the current inflation rate.

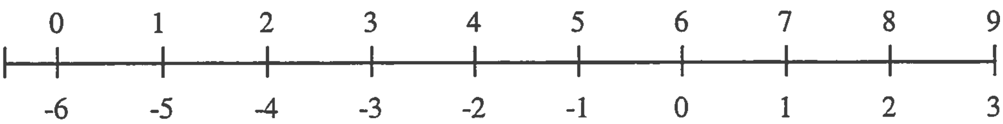
If data available on preproductive costs are nominal (relative to the current period) for the year the expense occurred, then they must be adjusted relative to the current time period using either the inflation rate and then the real interest rate or the actual nominal interest rate for the years in question in order to make the preproductive costs compatible with current end-of-year values. Given the need in such a nominal approach to consider multiple nominal interest rates, it is not recommended for projected budgets. When preparing historical estimates, the nominal approach may be used if year-specific data on preproductive costs are available and the desire is to compute an exact historical cost for a specific set of assets; otherwise, the real approach suggested for projected estimates may be used.

The Task Force recommends that preproductive costs be computed for each preproductive year using current nominal CAR data. These costs should be adjusted to the end of the respective year using the current nominal interest rate. The Task Force suggests that

these costs be adjusted to reflect expenditure at the end of their period of occurrence relative to the current one by using the current nominal interest rate for the current year and the real interest rate for years prior to the current year.

For historical budgets, the Task Force suggests the use of historical costs and nominal interest rates only in cases where there is excellent data and the desire is to estimate costs for a specific asset structure.

To make these points clear, consider a simple example where a farmer plants Christmas trees in year 1 and harvests them all in year 7 (assuming no residual crop in the eighth year). The CARs for each year are adjusted to be in nominal terms at the end of the seventh year. These values are also real values for this time point because the end of this year is the point at which CARs are estimated. The constant real interest rate is assumed to be 2% with a nominal rate of 7.1%. This implies a 5% rate of inflation [(.02)+(.05)+(.02)(.05) = .071] during the current year. To make the time points explicit, consider a time line like that presented in Chapter 2 where the numbers above the line consider the current period to end at 7 while the numbers below the line consider it to end at 1.



Points 0 and 6 are then the same point (the beginning of the current period), but numbered in alternative fashions. Given the normal convention that the end of the current period is point 1 and using negative indexing to reflect preproductive costs, the value of all CAR items at the beginning and end of the first period are presented in Table 10.1. It is assumed that all expenses occur in the middle of the year and are then adjusted to the end of the respective year using the nominal interest rate for the current year because the data are assumed to be in nominal terms for the current year. This means that they will accrue operating interest at the current nominal interest rate. Because these costs occur prior to the current period (i.e., they are preproductive costs) they will also accrue interest between their year of occurrence and the current period. To reflect this opportunity cost of financial capital, the preproductive costs must be adjusted accordingly. We assume that inflation is zero in all but the current period, which means that they are adjusted using the real interest rate for all periods except the current one, and using the nominal interest rate for the current period. Returns are assumed to occur on December 31. Notice that the nominal interest rate used within years for adjusting the expenditures to year end is 7.1%. The nominal interest rate used between years (except between 0 and 1) to adjust values to previous or future periods is equal to the real rate of 2%. Consider first the costs of $1,500 in the establishment year. It is assumed that this is the projected nominal cost for the current year and that this cost will occur on midnight June 30. This is adjusted to the end of the year using the nominal interest rate of 7.1% as suggested by equation 2.15. This is repeated here for convenience.

$$ic = R_t^{mn}(1 + i)^{\frac{mn}{12}} - R_t^{mn} \qquad (2.15)$$

where R_i^{mn} is a nominal expenditure occurring mn months from the end of the year t. If the interest charge is given by ic, then the value of the expenditure R_t^{mn} at the end of the year is

$$R_t = R_t^{mn}(1 + i)^{\frac{mn}{12}} \qquad (10.1)$$

where the 0 superscript on R_t is suppressed. This gives a value of \$1,552.3369 [(1,500)(1.071)$^{.5}$] because the payment occurs at midyear. Similarly, the cost in the second year of \$190 is adjusted to the end of that year to obtain \$196.6293 [(190)(1.071)$^{.5}$]. Because the costs in the establishment year did not occur during the harvest year but during the fifth year prior to it, they should be adjusted to reflect opportunity interest. This is done using the real interest rates for each year prior to the harvest (current) year and the nominal interest rate reflecting inflation level in the current year. Thus the cost of \$1,552.3369 is adjusted to yield \$1,835.593 as follows:

$$\begin{aligned} \textit{Value of establishment year expenditure at end of year 1} &= (1{,}552.3369)\,(1.02)^5\,(1.071) \\ &= (1{,}552.3369)\,(1.10408)\,(1.071) \\ &= (1{,}713.904)\,(1.071) \\ &= 1{,}835.593\,. \end{aligned}$$

This can be done for each year as in Table 10.1. Notice that in year 0 there is no adjustment because these costs are already in year-end values. Total preproductive costs are then \$2,931.512 in end-of-year 1 values. These can be adjusted to the beginning of the year using the nominal interest rate as follows:

$$\begin{aligned} \textit{Value of preproductive expenditures at beginning of year 1} &= \frac{(2{,}931.512)}{(1.071)} \\ &= 2{,}737.172\,. \end{aligned}$$

Costs in the production year of \$1,000 are adjusted to the end of the year using the nominal interest rate and are equivalent to \$1,034.89. Total costs for the year are then \$3,966.403 [(1,034.89) + (2,931.512)]. These are then subtracted from sales revenue of \$4,000 to obtain net returns in end-of-year dollars of \$33.597.

TABLE 10.1 Costs and Returns for Production of Christmas Trees

		Year	Inflation rate for within-year adjustments	Nominal i for within-year adjustments	Inflation rate for between-year adjustments	Nominal i for between-year adjustments
Real interest rate	0.02					
Inflation rate (current year)	0.05	-6	0.05	0.071	0	0.02
Nominal interest (current year)	0.071	-5	0.05	0.071	0	0.02
		-4	0.05	0.071	0	0.02
		-3	0.05	0.071	0	0.02
		-2	0.05	0.071	0	0.02
		-1	0.05	0.071	0	0.02
		0	0.05	0.071	0	0.02
		1	0.05	0.071	0.05	0.071

Year	Nominal cost at expenditure point in year i	Nominal income at end of year i	Nominal cost at end of year i	Cost adjusted to end of year 0	Income adjusted to end of year 0	Cost adjusted to end of year 1	Income adjusted to end of year 1	Net Income adjusted to end of year 0	Net Income adjusted to end of year 1
-5	1,500		1,552.336948	1,713.905	0.000	1,835.593	0.000	-1,713.905	-1,835.593
-4	190		196.6293467	212.838	0.000	227.949	0.000	-212.838	-227.949
-3	190		196.6293467	208.665	0.000	223.480	0.000	-208.665	-223.480
-2	190		196.6293467	204.573	0.000	219.098	0.000	-204.573	-219.098
-1	190		196.6293467	200.562	0.000	214.802	0.000	-200.562	-214.802
0	190		196.6293467	196.629	0.000	210.590	0.000	-196.629	-210.590
1	1,000	4,000	1,034.891299	966.285	3,734.827	1,034.891	4,000.000	2,768.542	2,965.109
Total cost, revenue, net return				3,703.458	3,734.827	3,966.403	4,000.000	**31.370**	**33.597**
Total preproduction cost, revenue, net return				**2,737.172**	0.000	**2,931.512**	0.000	-2,737.172	-2,931.512

ENTERPRISE ISSUES

Crops

Some crops may entail multiple preproductive years but only one production year. Examples include Christmas trees, such as the above example, and nursery products. For these crops, the problem to be addressed is not the allocation of preproductive costs over several production periods, but rather the correct procedure to use in discounting (or compounding) the annual preproduction and production costs. Assuming the goal is to estimate CARs at the end of the production year, the preproductive costs should be compounded to reflect the time value of money. Total compounded preproductive costs are then added to production year costs, and this total is subtracted from the gross returns estimates to get net returns in current dollars.

Another issue that arises for crops is determining the first operation for site preparation. Recall that the first expense associated with establishing a new crop determines the beginning of the preproductive period. The nature and cost of this first operation depends largely on the previous crop or use of the land. The condition of the land prior to the first site preparation operation should be specified to allow those using the CAR estimates to adjust costs accordingly. For example, when a new tree crop is planted to replace an old one, do we charge the cost of removing the old trees to the preproductive costs of the new orchard or do we charge the cost of removing the new orchard at the end of its life? A farmer in this situation pays for removal prior to planting the new enterprise, so we suggest that the costs of removal be included as establishment costs for the new enterprise. What if the new orchard is being planted where no orchard existed previously? The costs of removal are not paid by producers prior to planting in this case, so no removal costs are included in preproductive costs.

Some crops entail enterprise specific capital costs that do not match the life of the enterprise. An example is hop enterprises. Typically, more than one hop rootstock planting is used during the life of the hop enterprise. For cases such as this, the costs of purchasing and planting the rootstock are allocated over the shorter expected life of the rootstock instead of the expected life of the enterprise.

A final issue to consider is whether preproductive costs are ever involved in producing annual crops. Practices such as terracing, leveling, or tiling may be performed prior to production of annual crops. These practices result in benefits over a period of many production years, and should not be charged as annual expenses. Should they be treated as establishment costs? These practices are not really tied to the life of the enterprise, so they are not enterprise specific capital. Their costs are ultimately reflected in the land values to which they are attached. See Chapter 6 on machinery, buildings, and equipment, and Chapter 7 on land for a discussion of the treatment of these costs.

Livestock

The most significant preproductive cost for livestock enterprises is the cost of acquiring breeding or milking stock. Accurate estimation of this cost is difficult because many livestock operations raise many of their own replacement animals, often in the same or similar manner as their market animals. This makes the identification and estimation of costs specifically tied to raising replacement animals difficult and results in inaccurate cost estimates. Ways to account for establishment costs in livestock enterprises are (1) use the traditional method that allocates preproductive costs based on straight-line depreciation and opportunity interest; (2) capitalize the price of purchased replacement animals or actual costs of the production of raised replacement animals over the life of the breeding livestock; (3) use current costs of production for replacement animals in the production system treated as a whole in a steady-state type of analysis; (4) use market values for replacement animals based on replacement rates (cull rates) as an opportunity cost for a steady-state analysis similar to (3); and (5) use historic costs of raising replacement animals as their value based on replacement rates (cull rates) as an opportunity cost for a steady-state analysis similar to (3). These methods are each discussed in the section entitled Allocation Methods.

DETERMINING PREPRODUCTIVE COSTS (NET RETURNS)

Preproductive costs are estimated by calculating the negative of preproductive net returns in each preproductive year and then adjusting them to the end of the last preproductive year. Net preproductive costs for an enterprise are calculated as

$$PPC = \sum_{j=1}^{J} (1+r)^{J-j}(-R_j) \qquad \textbf{(10.2)}$$

where

PPC	=	total preproductive cost
j	=	index for j[th] preproductive year
J	=	length of preproductive period in years
r	=	real interest rate and
R_j	=	real net return in year j.

PPC is calculated in the same units as the productive years of the enterprise (usually on a per acre or per head basis). R_j measures annual net returns for preproductive years of the enterprise, and is calculated as total returns minus total annual cost. Equation 10.2 assumes that the R_j values are adjusted to year-end values on the last day of year j by including nominal interest on operating capital to reflect the cost associated with payment of expenses earlier in the year. The real interest rate, r, is used to calculate the opportunity costs of these expenditures in adjusting them from each year in the preproductive period to the production periods. If the preproductive costs are expressed in nominal values for the preproductive years, they must instead be adjusted by a nominal interest rate. These can then be adjusted to the end of the first production period by multiplying them by (1+i) where i is the nominal interest rate thus including inflation for the first productive year. If the discounted sum of preproductive net returns is positive then it is included in the CAR as a revenue instead of an expense. An example might be where yields and prices for a year of alfalfa establishment are so large that they cover the total costs of establishment.

Nominal preproductive CAR estimates for alfalfa are shown in Table 10.2. The preproductive period is one year. The net return in the preproductive year is $-157.89, which is calculated by subtracting the preproductive cost of $322.059 from total preproductive returns of $164.17. With a real interest rate of 5%, an inflation rate of 2%, and a nominal rate of 7.1%, preproductive cost is $157.89 using equation 10.2. Because J=1, no compounding is required; the preproductive cost is already estimated as of the end of the preproductive year. These costs could be multiplied by (1+i) to put them at the end of the first productive year rather than the end of the preproductive year.

TABLE 10.2 Establishment Year CARs for Alfalfa Hay (i = 7.1%)

Cost or Revenue	Description	Units	Quantity	Price/Unit	Months to end of period	Implicit interest factor	Value at end of period
Alfalfa Hay	July Cutting	ton	1	$80.00	5	1.029	82.32
Alfalfa Hay	August Cutting	ton	1	$80.00	4	1.023	81.85
Total Revenue							**164.17**
Seed	Alfalfa	lb	20	2.95	8	1.047	61.76
Inoculant	Alfalfa type	pkg	0.5	2.4	8	1.047	1.26
Fertilizer	N	lb	15	0.25	9	1.053	3.95
	P205	lb	60	0.23	9	1.053	14.53
	K20	lb	190	0.15	9	1.053	30.00
	Boron	lb	2	2.38	9	1.053	5.01
	Lime	ton	3	16	9	1.053	50.53
Weed Control	Balan	qt	3	4.13	9	1.053	13.04
	Custom app	acre	1	4	9	1.053	4.21
	2,4-DB	gal	0.63	40.5	8	1.047	26.71
	Custom app	acre	1	4	8	1.047	4.19
Machinery Costs		acre	1	77.34	6	1.035	80.04
Labor		hour	4.37	6	4	1.023	26.83
Total Cost							**322.06**
Net Return							**-$157.89**

Almond preproductive costs are shown in Appendix 10A and summarized in Table 10.3. The example assumes a nominal interest rate of 9% and a real rate of 4% with an implied inflation rate of $\pi = \frac{i - r}{(1 + r)} = \frac{(0.09 - 0.04)}{1.04} = .048077$. It is assumed all expenses are adjusted to the end of each preproductive year using the nominal rate of interest. The total almond preproductive period is six years, and the net returns for each of these six years vary. The total estimated life of the trees is 25 years, including the preproductive period. The first almond crop is harvested in year 4, and full production is not reached until year 7. Using equation 10.2 with r = 4%, J = 6 years, and R_j as shown in Table 10.3, the total preproductive cost for almonds adjusted to the beginning of year 7 is estimated as $4,494.67. For example, the first year cost of $1,895 (in end-of-period 6 nominal terms) accrues interest for five years from the end of year 1 to the beginning of year 7. This gives an accrued cost of $2,305.557 [$(1,895)(1.04)^5$]. This could be adjusted to the end of year 7 by multiplying by the interest rate for the production year.

TABLE 10.3 Annual Preproductive Net Returns for Almonds

Year	Net Return ($/acre) at end of year i	Net Return adjusted to the end of year 6
1	-1,895	-2,305.557
2	-718	-839.958
3	-788	-886.393
4	-600	-648.960
5	-70	-72.80
6	+259	+259.00
Sum		-4,494.669

Source: Appendix 10A. Sample Costs to Establish and Produce Almonds in the Northern San Joaquin Valley.

ALLOCATION METHODS

Once preproductive costs are determined, they must be allocated over time to the production enterprise if the enterprise has more than one production period. There are a variety of ways to allocate these costs. Examples from alfalfa, almond, and dairy enterprises will be used to illustrate the methods suggested.

Traditional Budgeting Method

The first method to consider is the traditional one described in equations 6.5 and 6.6. The traditional method allocates ownership costs of durable assets to enterprise CAR estimates based on charges for opportunity interest and service reduction/depreciation (Garst). Although these methods are most commonly used for machinery, equipment, and buildings, the same principles apply to establishment costs for multiyear enterprises (Casler and White; Chapter 6 of this report). Including depreciation and interest charges is consistent with economic theory. Depreciation expenses represent the decline in value of an asset over its useful life due to age, use, and obsolescence (Castle, Becker, and Nelson). Interest charges represent the opportunity cost of capital invested in assets.

Annual establishment depreciation expense (D) is generally calculated using straight-line depreciation as

$$D = \frac{(PPC - SV)}{(N - J)} \qquad \textbf{(10.3)}$$

where SV is the terminal or salvage value of the enterprise at the end of its life valued in the same dollars as total preproductive cost, J is the number of preproductive years, N is the total life of the enterprise, and N-J is the productive life of the enterprise. It is assumed that PPC is expressed as a beginning-of-period value. If SV is expressed in real dollars at the end of the useful life, it enters equation 10.3 unadjusted. If SV is expressed in nominal dollars, it should be deflated by $(1+\pi)^{N-J}$ where π is the assumed annual inflation rate over the remainder of its life. Annual depreciation expense for alfalfa establishment, assuming a salvage value of 0 and a remaining life of 4 years, is $39.472 [(157.889)/(4)]. Depreciation on the almond orchard, assuming a 0 salvage value and a 19-year remaining life, is calculated as $236.562 [(4,494.669)/(19)] annually.

Annual opportunity interest expense (OC) is typically calculated as

$$OC = \left(\frac{PPC + SV + D}{2}\right)(r)\,. \qquad \textbf{(10.4)}$$

This estimates annual interest on preproductive cost based on its average value over the life of the enterprise (Boehlje and Eidman). Kay (1974) and Walrath have shown the traditional method of calculating depreciation and interest expenses with $OC_{trad} = \left(\frac{PPC + SV}{2}\right)$ (r) underestimates actual costs in the sense that it will not fully recover initial investment. The estimate of annual depreciation is added back in the numerator in equation 10.4 to better reflect the actual opportunity cost of holding the asset (Chapter 6; Walrath; Kay (1974); Watts and Helmers (1979)). Using a real interest rate of 5% for the alfalfa example, annual opportunity interest expense for alfalfa preproductive cost is calculated with equation 10.4 as [(157.889 + 0 + 39.472)(.05)]/2 = $4.934, whereas opportunity interest at a 4% annual rate on the almond preproductive cost is [(4,494.669 + 236.56)(.04)]/2 = $94.625.

Total annualized preproductive cost using the traditional budgeting approach (A_{TB}) is therefore

$$A_{TB} = D + OC. \qquad \textbf{(10.5)}$$

This annualized preproductive cost is included in annual production budgets for multiyear enterprises. Total annualized preproductive cost for alfalfa using equation 10.5 is (39.472 + 4.934) = $44.406. Annualized almond preproductive cost estimated using the traditional budgeting method is 236.56 + 94.6246 = $331.186.

Although the concepts of depreciation and interest are proper for handling preproductive costs, implementing these concepts often proves to be awkward and inaccurate. Preproductive costs per unit must be calculated for each year of the preproductive period. Calculation of depreciation expenses requires selection of a depreciation pattern, and the pattern selected often does not reflect actual changes in value. Although depreciation seems inappropriate for those time periods when assets appreciate in value, it is certainly reasonable to calculate depreciation for assets that provide services over a finite useful life (United States Department of the Treasury). Thus, depreciation patterns are usually selected to simply recover total asset basis, with little emphasis on their pattern over time.

Interest calculations are also perplexing for investments in multiyear enterprises. An interest rate must be chosen that reflects the cost of capital to the firm, and applied to appropriate valuations of total preproductive cost. Given the changes in value of multiyear enterprise investments, selecting the "correct" value to use in calculating an opportunity cost is difficult. As suggested in Chapters 2 and 6, a more accurate alternative is to use the cost recovery method to allocate precisely the preproductive costs.

Cost Recovery (Annuity) Method

Cost recovery is used to recover combined charges for depreciation and interest over an asset's life, and this approach works well for preproductive costs of multiyear enterprises. The cost recovery method accrues annual preproductive returns to a future value at the end of the preproductive period, then amortizes these costs over the productive life of the enterprise. The resulting annual amortization charge includes both interest and depreciation expenses. This approach applies equally well to crop and livestock multiyear enterprises. This is exactly the approach suggested in Chapter 2, equation 2.31 and in Chapter 6, equation 6.8.

The first step in allocating preproductive costs using the cost recovery method is to calculate total preproductive cost, again following equation 10.2. This represents the value of the costs at the beginning of the productive period. Next, annualized real preproductive cost (A_{CR}) is calculated as

$$A_{CR} = \frac{\left(V_0 - \dfrac{V_n}{(1+r)^{(N-J)}}\right)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^{(N-J)}}}{r}\right)} = \frac{\left(PPC - \dfrac{SV}{(1+r)^{(N-J)}}\right)}{\left(\dfrac{1 - \dfrac{1}{(1+r)^{(N-J)}}}{r}\right)} \qquad \textbf{(10.6)}$$

where J is the number of preproductive years, N is the total life of the enterprise, and SV is the salvage value of the enterprise in the same dollars as PPC. A_{CR} can also be computed using the standard payment function (such as PMT in EXCEL) on financial calculators or spreadsheets. In such cases the present value is $\left(PPC - \frac{SV}{(1+r)^{N-J}} \right)$. The end-of-the-year payment option should be used. This annualized real preproductive cost is then adjusted to the end of the first year by multiplying it by $(1+\pi)$ where π is the inflation rate and by $(1+\pi)^j$ for periods $j > 1$ if a nominal analysis for periods in the future is used. For further discussion, see equation 2.32 and the analysis following.

Annualized preproductive cost for the alfalfa example can be calculated using equation 10.6. The total preproductive cost was previously calculated as PPC = \$157.89. With r = 5%, SV = \$0, N = 5, and J = 1 we can compute A_{CR} as

$$A_{CR} = \frac{\left(157.89 - \frac{0}{(1.05)^{(5-1)}} \right)}{\left(\frac{1 - \frac{1}{(1.05)^{(5-1)}}}{.05} \right)} = 44.5268,$$

which is slightly greater than the annualized preproductive cost of \$44.406 estimated using the traditional budgeting approach. This beginning-of-year value could be multiplied by the inflation rate of 2% to make it a nominal value at the end of period 1 ((44.527) (1.02) = 45.417). This value would remain the same for future periods if the inflation rate for these future periods were assumed to be zero. Alternatively, it could be increased each year to account for projected inflation.

The annualized cost (A_{CR}) for the almond example is \$342.218, assuming PPC = \$4,494.67, r = 4%, SV = \$0, N = 25, and J =6. If there is inflation in the current year then this real annuity must be adjusted to the end of the year to be comparable with other CARs. This inflation-adjusted annuity is \$358.6706 [(342.2179)(1.048077)]. A year-by-year analysis for the almond example is contained in Table 10.5 where it is assumed that inflation of 4.8077% occurs in year 7 only. The nominal interest rate is assumed to be 9% during year 7 and equal to the real rate of 4% during all other years. Column 1 lists the expenditures each year in nominal values. Because there is assumed to be no inflation during the preproductive period, these are also real values as of the end of year 6. Rather than charging the enterprise the preproductive costs in column 1 over each preproductive years of the enterprise, the annualized preproductive costs equaling \$358.6706 are charged each year during the production period. The net present value of the annual costs for the first six years shown in column 1 equal the amortized preproductive costs for years 7 through 25 in column 2.

Watts and Helmers (1981) illustrate that the cost recovery method is preferred over the traditional method under conditions of inflation. Walker and Kletke point out that the cost recovery method provides more accurate estimates when flows occur over time (a characteristic of establishment costs for perennial crops). A formal mathematical approach accounting for variable productivity over time has been developed by Burt (1992) and is discussed in Appendix 10B.

The cost recovery method requires almost the same data as the traditional budgeting method. No assumption of depreciation patterns is needed because equation 10.6 does not depend on a functional form, but rather is based on the value of preproductive cost and the salvage value of the enterprise.

Current Cost Method

Another method available for allocating preproductive costs includes the current costs of establishing some portion of a multiyear enterprise in annual production CAR estimates. For example, a dairy budget might include the operating and capital costs for a cow and her share on a percentage basis of a replacement animal. This approach is commonly used in constructing livestock enterprise CAR estimates (Smith, Knoblauch, and Putnam; McSweeny and Jenkins; Foley and Justus; USDA, 1990). USDA (1991) also has used this approach in estimating tree fruit enterprise CARs.

The primary advantage of the current cost method over the previous two methods is simplicity. Growers report their total costs for a multiyear enterprise, including costs for portions of the enterprise that are not yet productive. They also specify the relative rate at which replacement of the enterprise is occurring (e.g., the number of replacement animals added to a breeding herd, or the number of acres of new orchard being developed). Average costs, returns, and replacement rates can then be calculated. This method represents a type of "long-run equilibrium" where it is assumed that the enterprise is in a "steady state" and establishment costs are constant year after year. Thus the inventories of cows, heifers, sows, immature trees, mature trees, rootstock, vines, and the like are assumed to be the same at the beginning and end of each year. Sales of cull animals will balance with new animals added, trees removed will balance with trees beginning to bear, and so forth. Because assets are not normally bought and sold each period, Chapter 2 suggested ways to compute an annuity that represents the costs of holding and using the asset. This approach is suggested in equation 10.6. If the number and age distribution of assets in the operation do not change, a more direct approach is to use the current cost method (equation 10.7 directly).

The easiest way to visualize the current cost method is to consider an example such as a dairy cow. Suppose an asset (the dairy cow) is purchased at the beginning of the year with beginning-of-year nominal value V_0^j where j denotes that this is the jth asset. Assume that operating costs associated with the asset during the year are given by C_1^j and are already adjusted to the end of the year using the nominal interest rate assumed. At the end of the period, assume that the asset is sold with nominal (and real) value V_1^j. The net cost of holding and using the asset during the period (NC_1^j) is then given by

$$NC_1^j = iV_0^j + (V_0^j - V_1^j) + C_1^j. \qquad \textbf{(10.7)}$$

where V_k^j is the value of the asset at the end of period k and C_1^j is the operating cost of the asset during period 1. This can also be written using the real interest rate (r) as follows

$$\begin{aligned} NC_1^j &= rV_0^j(1+\pi) + [(1+\pi)V_0^j - V_1^j] + C_1^j \\ &= rV_0^j + \pi r V_0^j + V_0^j + \pi V_0^j - V_1^j + C_1^j \\ &= (\pi + r + \pi r)V_0^j + V_0^j - V_1^j + C_1^j \\ &= iV_0^j + [V_0^j - V_1^j] + C_1^j . \end{aligned} \tag{10.7r}$$

The first line adjusts the nominal value V_0^j to a real end-of-year value by multiplying it by the inflation rate and then applies a real interest rate to evaluate opportunity cost. Real economic depreciation is given by $(1+\pi)V_0^j - V_1^j$ because V_0^j is a nominal beginning-of-period value. The lines following show the equivalence in the expressions 10.7 and 10.7r using the identity $i = \pi + r + \pi r$. The first term in each expression is opportunity interest, the bracketed term is economic depreciation, and the last term is the operating and maintenance cost associated with the asset. Any purchases of assets (such as breeding animals or trees) are counted as an expense this period in the form of V_0^j whereas any assets sold (such as cull cows or ewes) are counted as a revenue in the form of $-V_1^j$. Only a portion of the assets associated with most enterprises are usually bought and sold in a given period. For assets not bought or sold during the period it is standard in CAR estimation to assume that $(1+\pi)V_0^j = V_1^j$ so that the net cost is just $NC_1^j = r(1+\pi)V_0^j + C_1^j = (i - \pi)V_0^j + C_1^j$. For an entire enterprise the net cost of holding and using the assets for the first period is then

$$\begin{aligned} \sum_{j=1}^{m} NC_1^j &= \sum_{j \neq k} \left(r(1+\pi)V_0^j + C_1^j\right) + \sum_{j=k} \left(r(1+\pi)V_0^j + ((1+\pi)V_0^j - V_1^j) + C_1^j\right) \\ &= \sum_{j=1}^{m}\left(r(1+\pi)V_0^j + C_1^j\right) + \sum_{j=k}\left((1+\pi)V_0^j - V_1^j\right) \\ &= \sum_{j=1}^{m} r(1+\pi)V_0^j + \sum_{j=1}^{m} C_1^j + \sum_{j=k}(1+\pi)V_0^j - \sum_{j=k} V_1^j \end{aligned} \tag{10.8}$$

where k indexes those assets that are bought or sold during this period and the index m includes all assets associated with the enterprise. For all assets not bought or sold, we implicitly assume that $(1+\pi)V_0^j = V_1^j$.

This implies that we use as the net cost of these assets their opportunity interest, operating costs, the purchase of any replacement items, and any revenues from their sale.

In many situations an enterprise may produce rather than purchase assets. An example is beef heifers or gilts. In this case, the term $\sum_{j=k} (1+\pi)V_0^j$ would be excluded from equation 10.8. The costs would be computed using 10.9

$$\sum_{j=1}^{m} NC_1^j(current\ cost) \equiv \sum_{j=1}^{m} r(1+\pi)V_0^j + \sum_{j=1}^{m} C_1^j + \sum_{j=k} -V_1^j . \tag{10.9}$$

Note, however, that current costs associated with producing these assets for future use, $\sum_{j=1}^{m} C_1^j$, are still included. Thus for example, the cost of feeding a heifer this year to be of breeding age would be included. The current cost method uses this approach to account for costs of producing and operating assets and also includes revenues from the sale of the assets.

The current cost method can be first illustrated using the alfalfa example where there are no assets purchased but there are operating costs associated with a portion of the operation from which there is minimal saleable production. If a given percentage of total acreage is established each year, then the same percentage of establishment cost should be included in the production CAR estimate. One year of establishment and four years of production imply that 25% of every producing acre (20% of total acres) is being established each year. Therefore, 25% of the total alfalfa preproductive cost of \$157.89 (Table 10.2) should be included to represent preproductive costs in the production CAR estimate. This represents an annual preproductive cost of \$39.472. If the annual returns to an acre of alfalfa yielding 4 tons per year are \$379.433 and annual costs, excluding establishment, are \$282.539, then returns over annual costs are \$96.894. Returns over all costs would then be \$57.422 (96.894-39.472). Table 10.4 contains a CAR estimate for an alfalfa system. The example assumes a real interest rate of 5%, an inflation rate of 2%, and a nominal interest rate of 7.1%. The system is not based on a one-acre unit but rather is based on five acres of land, four in production and one in establishment. If we then convert these five acres to a one-acre unit, we have a "representative" acre with 80% in production and 20% in preproduction. Because land charges were not included in any of the costs, an acre of productive land in this system requires 1.25 acres of land. If land rent were \$40.00 per acre and paid at the end of the year, the owner of this operation would have a net return of \$7.422 [57.422-(40)(1.25)] per acre. Total returns for the five-acre system are \$229.686 (1,681.902 - 1,452.216). With a land charge of \$40.00 per acre this gives a net return of \$29.686 (229.686-200). On a total acre basis this is \$5.937 (29.686/5) per acre. On a production acre basis this is \$7.422 per acre ((5.937)(1.25) or 29.686/4). If land rent were paid over the year, operating interest would need to be charged on this expenditure.

There are several limitations of the current cost method that must be recognized. First, the time value of money is not explicitly incorporated into the analysis. Preproductive costs of future productive resources are charged against current productive resources because the purchases and sales included are not for the exact same assets. This is only appropriate when estimating costs for an enterprise that is in long-run equilibrium and where the initial start-up costs or conditions are no longer important.

A second problem relates to changes in technology and production practices. Current preproductive practices may differ from the practices used to establish the current productive portion of the enterprise. For example, an orchard may switch to higher densities of tree plantings, resulting in significantly higher preproductive costs relative to the existing productive orchard. Mixing the high-density preproductive costs with low-density production CARs results in incorrect estimates of profitability. In fact, the high-density planting should be treated as a new enterprise, rather than a replacement of the low-density planting.

Changes in establishment rates for new enterprises among growers can lead to problems in estimating CARs. If the rate of new establishment within an enterprise is constant among growers and represents the long-term replacement rate needed to maintain a productive enterprise, then CAR estimates based on the current cost method reflect long-run estimates of economic profitability (in the absence of technological or cultural changes discussed above). However, in some years weather or market factors may cause short-term shifts in establishment rates, leading to abnormally high or low preproductive costs in current or succeeding years.

As an example, consider an unusual freeze occurring in the citrus industry in California. A severe, prolonged freeze would potentially damage or destroy many trees, but the real extent of this damage may not be realized until up to one year later, when trees actually die or demonstrate reduced production levels. Establishment rates in citrus groves would increase over several years due to tree losses, changing the percentages of bearing trees for several years. Resulting CARs attributed to productive trees would increase substantially in the short run, due to higher establishment rates. This leads to CAR estimates that are not reflective of long-run productive citrus enterprises, if the purpose of the estimates is to prepare management budgets for recommended production practices. However, if the purpose is to estimate actual historical costs, no problem arises.

TABLE 10.4 Total Cost for 4 Acres of Alfalfa Hay and 1 Acre of Alfalfa Establishment (i = 7.1%)

Cost or Revenue	Description	Units	Quantity	Price/ Unit	Months to end of period	Implicit interest factor	Value at end of period
Alfalfa Hay	May Cutting	ton	3.6	$80.00	7	1.041	299.757
Alfalfa Hay	June Cutting	ton	5.6	$80.00	6	1.035	463.631
Alfalfa Hay (estab)	July Cutting	ton	1	$80.00	5	1.029	82.319
Alfalfa Hay	July Cutting	ton	6	$80.00	5	1.029	493.916
Alfalfa Hay (estab)	Aug Cutting	ton	1	$80.00	4	1.023	81.850
Alfalfa Hay	Sep Cutting	ton	3.2	$80.00	3	1.017	260.428
Production Year Revenue							1,517.733
Total Revenue							1,681.902
Establishment Costs							
Seed	Alfalfa	lb	20	2.95	8	1.047	61.761
Inoculant	Alfalfa type	pkg	0.5	2.4	8	1.047	1.256
Fertilizer	N	lb	15	0.25	9	1.053	3.948
	P205	lb	60	0.23	9	1.053	14.529
	K20	lb	190	0.15	9	1.053	30.005
	Boron	lb	2	2.38	9	1.053	5.011
	Lime	ton	3	16	9	1.053	50.534
Weed Control	Balan	qt	3	4.13	9	1.053	13.044
	Custom app	acre	1	4	9	1.053	4.211
	2,4-DB	gal	0.63	40.5	8	1.047	26.709
	Custom app	acre	1	4	8	1.047	4.187
Machinery Costs		acre	1	77.34	6	1.035	80.038
Labor		hour	4.37	6	4	1.023	26.826
Land	Rental	acre	0	40	0	1.000	0.000
Total Establishment Costs							322.059
Production Year Costs							
Fertilizer	P205	lb	240	0.23	9	1.053	58.114
	K20	lb	760	0.15	9	1.053	120.018
	Boron	lb	8	2.38	9	1.053	20.045
Insect Control	Furadan 4F	qt	4	17.04	7	1.041	70.943
Weed Control							
Post-Emerge (2 of 4 acres)	Poast plus	gal	0.52	22	6	1.035	11.839
	Crop oil	gal	0.52	8.08	6	1.035	4.348
	Custom app	acre	2	4	6	1.035	8.279
Post-Emerge (2 of 4 acres)	2,4-DB	gal	1.28	40.5	8	1.047	54.266
	Custom app	acre	2	4	8	1.047	8.374
Post-Emerge	Gramoxone extra	pt	4	4.04	10	1.059	17.111
	Surfactant	qt	1	2.71	10	1.059	2.869
	Custom app	acre	4	4	10	1.059	16.941
Hay Preservative	Fresh cut(80% of crop)	lb	96	1.35		1.000	129.600
Twine		bale	800	0.05		1.000	40.000
Labor		hour	27.16	6	4	1.023	166.729
Machinery Fuel		acre	4	11.95		1.000	47.800
Machinery Repairs		acre	4	27.31		1.000	109.240
Machinery & equipment	Depreciation & Interest	acre	4	60.91		1.000	243.640
Land	Rental	acre	0	40	0	1.000	0.000
Total Production Year Cost							1,130.156
Total Cost							1,452.216
Production Year Return							1,517.733
Production Year (Return - Cost)							387.576
Total Return							1,681.902
Total Return -Total Cost							229.687
Production Year Cost/Acre							282.539
Production Year Return/Acre							379.433
Production Year (Return - Cost)/Acre							96.894
Establishment Net Return/Productive Acre							39.472
(Total Return -Total Cost)/Acre							57.422

Market Value Method

The market value method allocates preproductive costs based on the market value of the preproductive investment in the multiyear enterprise. Market values are usually measured in terms of purchase prices for replacement animals in the case of dairy or breeding livestock enterprises. Total costs are then computed using equation 10.8. If there is an active market for the leasing of these assets, the annual lease payment could be used instead of $\sum_{j=k} \left((1+\pi)V_0^j - V_1^j\right)$. These costs can then be allocated on a per head basis to producing animals in the herd. For example, in using purchase and sales values, there may be .35 purchases of replacement gilts and .34 sales of cull sows for each sow in the herd. For multiyear crops, market value might be estimated by determining annual lease rates for productive crops. The market value method is similar to the current cost method in that revenue is included for the sales with value of V_1^j. Rather than including the costs of producing the asset in the term $\sum_{j=1}^{m} C_1^j$, as with the current cost method, the cost of purchasing the asset from the market is used.

The market value method is particularly appealing for livestock because it accounts for opportunity costs that may be lost through foregone replacement animal sales. It is also easy to compute. A replacement rate can be used to allocate the market values of replacement animals over the base herd or flock. If one is trying to reflect the profit of alternative enterprises on the farm, using the market value of replacements credits each enterprise (say, heifer production and the dairy herd) with the "appropriate" return and cost. Hence it can be used at any time, preproduction or later.

There are some problems in using the market value method for handling preproductive costs. Markets for replacement animals or multiyear crop leases may not exist in all locations, or there may be unusual price movements due to thin markets. Furthermore, current market values may not cover all the costs incurred in producing the multiyear assets, or may be distorted to reflect future earnings as opposed to historical costs. This may not be as much of a concern in a long-run projected budget. The market value method does not account for the time value of money during the life of the enterprise. Specifically, the cost of purchasing an asset this period is charged against the output from an asset purchased in prior periods. And sales of assets purchased in prior periods are evenly credited to all assets in use this period rather than to just the ones actually sold. As with the current value method, this method represents the costs of a long-run equilibrium situation that is not concerned with the initial start-up costs. Finally, as with the current cost method, determining the actual replacement rate to use to adjust the purchase cost of replacements is difficult. In the case of crop enterprises, separating the value of crop enterprises from land is difficult in estimating market values, often requiring a number of assumptions (Casler and White).

Historic Cost Method

The historic cost method is related to both the current cost and market value methods. As with the market value method, $\sum_{j=k} (1+\pi)V_0^j$ is included to represent the cost of productive assets and $\sum_{j=k} -V_1^j$ is included to account for revenue from current asset sales. Rather than using the market value of these assets, the cost of producing the asset is used to compute $\sum_{j=k} (1+\pi)V_0^j$. The historic cost method is very similar to the current cost method in that the costs of producing replacement assets (livestock) are included explicitly in the cost equation. But the historic cost method uses the cost of producing the replacements that actually enter the operation this year, some of which may have been incurred in prior years, whereas the current cost method includes the costs of assets being produced this year, many of which will not enter the productive operation until future periods. The historic cost method is a reasonable alternative to use when good data on market values are not available. The historic cost method is sometimes called the **raised value method** to emphasize that the cost of raising (producing) replacements, as opposed to their opportunity cost as valued by the market, is being used.

Recommendation

The use of market values is generally preferred to the current cost or historic value methods. The market value of the asset better reflects the opportunity cost of the expenditure. The historic cost (raised value) method is preferred for historical budgets as compared to the current cost method whereas the current cost method is more appropriate for projected budgets. The capital recovery method using market values is preferred to the market value method because the market value method does not account for the time value of money and the fact that most assets are held more than one period. All of the "equilibrium" methods suffer from this same criticism. The main advantages of the current cost, historic cost, and market value methods are ease of use and the explicit accounting for asset purchase (transfer from within operation) and sale (cull or otherwise).

Table 10.5 Allocation of Costs and Revenues for Almonds

Annual real interest	0.040000
Annual inflation rate	0.048077
Annual nominal i	0.090000
Total productive life	25
Productive period	19
Annual return	2,025.00
Annual cost	1,675.00
PV(0) or PPC	4,494.6685
Salvage	0.00
Real Annuity for PPC	342.2179

Year	Inflation rate between years	Nominal i between years
0	0.000	0.0400
1	0.000	0.0400
2	0.000	0.0400
3	0.000	0.0400
4	0.000	0.0400
5	0.000	0.0400
6	0.000	0.0400
7	**0.048077**	0.0900
8	0.000	0.0400

	1	2	3	4	5	6	7	8	9	10	11	12	13
Year	Annual Costs end j[2] ne 7$[3]	Amortized preproductive costs end j ne 7$	Annual return end j ne 7$	R[1] end 1 ne 7$ no annuity	Disc R end 0 ne 7$ no annuity	Disc R end 6 ne 7$ no annuity	Disc R end 7 ne 7$ no annuity	Net return end j ne 7$ annuity	Disc R end 0 ne 7$ annuity	Disc R end 6 ne 7$ annuity	Disc R end 7 ne 7$ annuity	Annuity value all years ne 7$	Disc Ann end 0 ne 7$
1	1,895.00			-1,895.00	-1,822.115	-2,305.557	-2,513.057					5.171	5.171
2	718.00			-718.000	-663.831	-839.958	-915.555					5.171	4.972
3	788.00			-788.000	-700.529	-886.393	-966.168					5.171	4.781
4	600.00			-600.000	-512.883	-648.960	-707.366					5.171	4.597
5	70.00			-70.000	-57.535	-72.800	-79.352					5.171	4.420
6	-259.00			259.000	204.691	259.000	282.310					5.171	4.250
7	1,755.53	358.6706	2,122.356	366.827	265.971	336.538	366.827	8.156	5.914	7.483	8.156	5.419	4.087
8	1,755.53	358.6706	2,122.356	366.827	255.742	323.595	352.718	8.156	5.686	7.195	7.843	5.419	3.929
9	1,755.53	358.6706	2,122.356	366.827	245.905	311.149	339.152	8.156	5.468	6.918	7.541	5.419	3.778

TABLE 10.5 (continued)

Year	1 Annual Costs end j ne 7$	2 Amortized preproductive costs end j ne 7$	3 Annual return end j ne 7$	4 R end 1 ne 7$ no annuity	5 Disc R end 0 ne 7$ no annuity	6 Disc R end 6 ne 7$ no annuity	7 Disc R end 7 ne 7$ no annuity	8 Net return end j ne 7$ annuity	9 Disc R end 0 ne 7$ annuity	10 Disc R end 6 ne 7$ annuity	11 Disc R end 7 ne 7$ annuity	12 Annuity value all years ne 7$	13 Disc Ann end 0 ne 7$
10	1,755.53	358.6706	2,122.356	366.827	236.447	299.181	326.108	8.156	5.257	6.652	7.251	5.419	3.633
11	1,755.53	358.6706	2,122.356	366.827	227.353	287.674	313.565	8.156	5.055	6.396	6.972	5.419	3.493
12	1,755.53	358.6706	2,122.356	366.827	218.609	276.610	301.505	8.156	4.861	6.150	6.704	5.419	3.359
13	1,755.53	358.6706	2,122.356	366.827	210.201	265.971	289.909	8.156	4.674	5.914	6.446	5.419	3.230
14	1,755.53	358.6706	2,122.356	366.827	202.116	255.742	278.758	8.156	4.494	5.686	6.198	5.419	3.105
15	1,755.53	358.6706	2,122.356	366.827	194.343	245.905	268.037	8.156	4.321	5.468	5.960	5.419	2.986
16	1,755.53	358.6706	2,122.356	366.827	186.868	236.447	257.728	8.156	4.155	5.257	5.731	5.419	2.871
17	1,755.53	358.6706	2,122.356	366.827	179.681	227.353	247.815	8.156	3.995	5.055	5.510	5.419	2.761
18	1,755.53	358.6706	2,122.356	366.827	172.770	218.609	238.284	8.156	3.841	4.861	5.298	5.419	2.655
19	1,755.53	358.6706	2,122.356	366.827	166.125	210.201	229.119	8.156	3.694	4.674	5.094	5.419	2.552
20	1,755.53	358.6706	2,122.356	366.827	159.735	202.116	220.307	8.156	3.552	4.494	4.898	5.419	2.454
21	1,755.53	358.6706	2,122.356	366.827	153.592	194.343	211.833	8.156	3.415	4.321	4.710	5.419	2.360
22	1,755.53	358.6706	2,122.356	366.827	147.684	186.868	203.686	8.156	3.284	4.155	4.529	5.419	2.269
23	1,755.53	358.6706	2,122.356	366.827	142.004	179.681	195.852	8.156	3.157	3.995	4.355	5.419	2.182
24	1,755.53	358.6706	2,122.356	366.827	136.543	172.770	188.319	8.156	3.036	3.841	4.187	5.419	2.098
25	1,755.53	358.6706	2,122.356	366.827	131.291	166.125	181.076	8.156	2.919	3.694	4.026	5.419	2.017
PV(0)[4]					**80.7783**				**80.7783**				
PV(1)													84.0094
PV(6)						**102.2103**				**102.2103**			
PV(7)							**111.4092**				**111.4092**		
$US_0(r,25)$[5]	15.62208												
CSC(1)[6]	5.1707746												

[1]R = net return
[2]end j = valued at the end of year j
[3]ne 7$ = uses the end of period 7 as the base for real calculations so the real and nominal rates are equal at this point
[4]PV(J) Present value in year J
[5]$US_0(r, 25)$ Uniform series having interest rate r and 25 periods
[6]CSC(1) Capital service cost calculated as the equivalent annual annuity at the end of year 1

Examples of Methods to Allocate Preproduction Costs: Dairy Cow Replacements

Four alternative methods of allocating the costs of raising or acquiring replacement heifers for dairy cows are illustrated in this section. The real price of replacement heifers at the end of the year is assumed to be $1,050, while the real price of cull cows is assumed to be $46.4 per cwt. A cull cow is assumed to weigh 1,200 pounds. Death loss over a 2.5-year productive life is assumed to be 2.5% for a net sales weight of 1,170 pounds (11.7 cwt). This gives a real sales value of $542.88. The 2.5-year life implies a replacement rate of 0.40. The cost recovery, market value, current cost, and historic cost methods are illustrated. All methods and the resulting analysis presented in Table 10.6 are based on the dairy farm example developed in Chapters 13 and 14 of the Task Force report and the CAR estimates presented in Appendix 13A. Milk, revenue, feed, and other costs are the same in all methods.

The first method discussed is the capital recovery cost (annuity) approach. The real price for a purchased heifer of $1,050 less the cull value of the milk cow ($542.88) must be allocated over the economic life of the cow, which is assumed to be 2.5 years. Using equation 10.6, a 2.5-year life, and a 5% real interest rate, the annual replacement cost of the cow is as follows:

$$A_{CR} = \frac{\left(1{,}050 - \dfrac{542.88}{(1.05)^{2.5}}\right)}{\left(\dfrac{1 - \dfrac{1}{(1.05)^{2.5}}}{.05}\right)}$$

$$= \frac{(1{,}050 - 480.5412)}{(2.296597)}$$

$$= 247.9576\,.$$

This is a real value applicable at the end of the year because PPC (1,050) and SV (522.88) are in end-of-period dollars. No cull income is included in total receipts because this would double count the cull value of the cow. No cost for a replacement heifer is included because this cost is also included in the capital recovery payment. Revenue, feed, and other costs are the same as in the market value and raised value methods. The net return per cow is $190.88.

The second method of allocating replacement costs among the milk cows is to use as the opportunity cost of the heifer, the market price at which it could be bought or sold. This cost is allocated among milk cows based on the replacement percentage of 40% and a cull percentage (with death loss) of 39%. The average nominal cull price taken from Table 13A.5 is $45.56 assuming equal sales each month. This gives cull receipts of $213.22 [(12 cwt/cow)(.39 cows)($45.56/cwt)]. The replacement heifer is assumed to be purchased at a real end-of-year price of $1,050. This is equivalent to an average nominal price of $1,031.36 over the 12-month period as shown in Tables 13A.2 and 13A.8. Revenue, feed, and other costs are the same as in the capital recovery and raised cost methods. The livestock investment cost ($r(1+\pi)V_0^n$) is based on the traditional method to value opportunity cost. We first compute an average inventory value in real terms as

$$\text{Average } V_0^r = \left(\frac{1{,}050 + 542.88 + 202.848}{2} \right) = \$897.864 \text{ where } \$202.848 \text{ is straight-line depreciation}$$

over 2.5 years. We can convert this average value to beginning-of-year nominal terms by dividing it by $(1 + \pi)$ to obtain \$863.33 [$(897.864)(1.04)^{-1}$]. Opportunity interest is then computed as [(863.33)(0.05)] = \$43.1665. Adjusting this to end-of-the-year prices will give \$44.8932 [(43.1665)(1.04)]. We could also compute this directly as [(897.864)(0.04)]. The net return using this method which adds revenue for cull sales, adds cost for the purchase of a replacement heifer, and only includes the opportunity interest for one year on the average value of livestock investment is \$186.55 as reported in the last row of Table 10.6.

The third method is the historic cost method, which uses the cost of producing a heifer in the herd as a proxy for the market value of a replacement. Based on the estimates in Table 13A.5A, the cost of raising a heifer to one year of age in end-of-year dollars is \$577.67 and the cost of raising the heifer during the second year (Table 13A.5B) until freshening is \$554.16. Given the 2-year lag in production, this gives a total real cost as of year end of \$1,160.71 [(577.67)(1.05)+554.16] compared to \$1,050 in the case of a market replacement. This translates into a nominal average price of \$1,140.10 as computed in Table 13A.8. Multiplying by the replacement rate of 0.40 gives the net purchase price of \$456.04 [(1,140.10)(0.4)] compared to \$412.54 in the market value case. Revenue is the same as with the market value and capital recovery methods. Feed and other costs for this enterprise budget are the same as with the market value and capital recovery methods. The net returns are \$137.38 per cow. This reflects the higher cost of raising as opposed to purchasing the replacement heifer.

The fourth method considered is the current cost method, which allocates all costs associated with raising replacement heifers to the dairy cow enterprise as direct costs of production. These estimates are developed using the costs of raising a heifer in Tables 13A.5AB, 13A.6AB and 13A.7. The costs of raising a heifer from birth to one year of age are in Tables 13A.5A and 13A.6A; the costs of raising a heifer from one year of age until freshening are in Tables 13A.5B and 13A.6B. The current cost method assumes a continuous inventory of replacement animals and so Table 13A.7 presents the combined costs of having both the first and second year replacement animal in the herd. Given the replacement rate of 40%, 40% of these costs are added to the costs of the milk cow instead of the cost of a replacement heifer. This method also assumes that almost all the female calves are used for the replacement activity and so sales are minimal. Feed costs, other variable costs, and fixed costs reflect both the costs associated with the dairy cow and those associated with her share of all replacements on the farm. Total farm costs are allocated on a per cow in the herd basis. There should be little difference between the historic cost and current cost methods except for the assessing of interest charges on the historic costs of raising the replacement, and any price level differences between the current and previous years. In this case the cost per cow is \$149.92.

TABLE 10.6 Different Methods of Allocating Heifer Costs in a Dairy Cow Budget (values in $/cow)

	Capital recovery	Market value	Historic value	Current cost
Item				
Revenue				
Milk Sales	2,652.04	2,652.04	2,652.04	2,652.04
Cull Sales	0.00	213.22	213.22	213.22
Bull Calf Sales	51.00	51.00	51.00	51.00
Heifer Calf Sales	61.20	61.20	61.20	2.27
Interest on Revenue	113.44	122.37	122.37	119.94
Total Receipts	2,877.68	3,099.83	3,099.83	3,038.47
Operating Costs				
Replacement Cost	0.00	412.54	456.04	0.00
Feed Cost	880.40	880.40	880.40	1,053.22
Other Operating Costs	699.39	699.39	699.39	776.06
Interest on All Operating Costs	65.09	82.08	83.87	75.37
Total Operating Costs	1,644.87	2,074.41	2,119.70	1,904.65
Allocated Overhead				
Labor Costs	522.42	522.42	522.42	602.23
Livestock Investment	247.96	44.89	48.77	60.32
Other Fixed Costs	271.55	271.55	271.55	321.35
Total Allocated Overhead	1,041.93	838.87	842.74	983.90
Total Costs	2,686.80	2,913.28	2,962.44	2,888.54
Net Returns	190.88	186.55	137.38	149.92

An examination of the net returns using the four methods in Table 10.6 indicates little difference among the methods. Any difference would depend on the relationship between current costs of heifer production, historic costs of heifer production, and the market value for fresh heifers.

RECOMMENDATIONS

Based on the relative advantages and disadvantages of each of the four approaches discussed, and given the nature of the production process for multiyear crop and livestock enterprises, the following recommendations are made for estimating and allocating preproductive costs.

The Task Force recommends that the cost recovery approach be used in preparation of projected CAR for multiyear crop enterprises. It overcomes the shortcomings of the traditional budgeting method, and provides an intuitive approach for allocating establishment costs on an annualized basis. It is particularly well-suited for CAR

estimates constructed for management purposes. The cost recovery approach can also be used for historical estimates but may require more data than is typically available from farm records. Therefore historical CAR estimates for multiyear crop enterprises, developed primarily to record economic costs incurred during a given year, may be constructed using the current cost method to reflect the input and price levels actually experienced.

The cost recovery approach is also the recommended method to estimate replacement costs included in projected CARs for multiyear livestock enterprises. This method is preferred for all projected livestock CAR estimates, regardless of their purpose. This method appropriately handles the costs of replacement animals and accounts for the time value of money in reasonable manner. If breeding stock or milking stock are replaced by purchasing replacement animals, the cost of the replacement animals should be allocated over the productive life of the breeding animals using capital recovery. Expenses associated with raising replacement animals can be distributed in the same manner. The market value method, when markets for replacement animals are reasonably well developed, and the current cost method, when markets for replacements are thin, provide a reasonable alternative in situations where it isn't feasible to apply the cost recovery method in preparing projected CARs. Historical CARs for livestock, constructed primarily to record economic costs incurred during a production period, should use the market value method when markets are well developed and data allows the separation of the replacement animal enterprise from the production enterprise. In other situations, the current cost method may be used.

Format of Reports

The Task Force recommends that multiyear crop enterprise preproductive costs be reported in the same format used for single-year enterprises. A report of the annual preproductive costs for each year of the preproductive period should be included in the CAR estimate. Annual cost recovery expenses, calculated using equation 10.6, should be included in production year budgets. Assumptions about discount rates, productive lives, and salvage values of multiyear crop enterprises should also be specified in production year CAR estimates.

The Task Force recommends that livestock establishment costs and historical multiyear crop cost estimates be reported in the same report as the nonestablishment annual costs. Assumptions or data gathered concerning replacement or replanting rates should be reported as well, to provide users with information about rates of "establishment."

COMPARING ANNUAL ENTERPRISES TO MULTIYEAR ENTERPRISES

Users of CAR estimates often compare returns among two or more enterprises. If all of the enterprises are annual, then a comparison of CAR estimates adjusted to year-end values is valid, assuming each CAR estimate is constructed in a consistent manner. (See the international comparisons chapter for a discussion of other issues surrounding CAR estimate comparisons.) However, if annual enterprise CAR estimates are compared to multiyear CAR estimates, a problem arises. Capital budgeting procedures have shown that two projects or investments with unequal lives can only be fairly compared when they are evaluated over an equivalent life (Copeland and Weston). This same reasoning applies to comparisons of enterprises with different productive time periods.

Cost and return estimates are converted to equivalent lives using the equivalent annual annuity approach, which is a 2-step process. First, the net present value (NPV) of each enterprise is calculated by discounting annual returns over the productive life of the enterprise using a real interest rate. Second, an equivalent annual annuity of each crop is calculated by dividing the net present value by the appropriate annuity factor to get an annual payment for comparison.

Estimating Net Present Value

Cost and return estimates for annual crops are expressed as net (returns minus costs) present values at the end of the production period, so no adjustments are necessary for these enterprises. Multiyear enterprises have production costs expressed in values as of the end of each production year, and these CARs occur at some point in the future or the past. Projected CARs must be discounted over the life of multiyear enterprises to estimate annual net returns comparable to returns from annual enterprises.

If the cost recovery approach is used to estimate annualized preproductive costs, then the costs of the preproductive period are accounted for in the CAR estimates for productive years of multiyear enterprises. The net present value of a multiyear enterprise at the end of the first year of its productive life is calculated as

$$PV(J+1) = \sum_{k=J+1}^{N} R_k (1+r)^{1-k+J} \qquad \textbf{(10.10)}$$

where R_k is the annual net return for the enterprise in year k after subtracting all costs of production, including A_{CR} as calculated in equation 10.6. It is often assumed that R_k is constant for all production years of the enterprise and denoted by R. For the almond example in Table 10.5, the real value of annual gross returns at the beginning of year 7 (actual production period) is assumed to be $2,025. With inflation of 4.8077% this gives an end-of-year value of $2,122.356 for year 7 and all years thereafter. Recall that J is the total years in the preproductive period and N is the years of life of the enterprise. If we want to discount this value to the beginning of the first productive period we must do so using the nominal interest rate because current year CARs are expressed in nominal dollars relative to the end of the period. This will give

$$PV(J) = \frac{\sum_{k=J+1}^{N} R_k(1+r)^{1-k+J}}{(1+i)} = \sum_{k=J+1}^{N} R_k(1+r)^{1-k+J}(1+i)^{-1} . \qquad \textbf{(10.11)}$$

Using the almond enterprise as an example with a real interest rate of 4% and no assumed inflation over the productive life of the trees, N = 25, J = 6, real returns in years 7-25 equal to $2,025.00 per year, annual costs (in real terms) in years 7-25 of $1,675, and real amortized preproductive costs equal to $342.2179, we can compute R_k (k=7,8,...,25) as = $7.7821[2,025-1,675-342.2179]. With inflation in year 7 of 4.8077%, this net return is equal to $8.1563 as reported in column 8 of Table 10.5. PV(7) is estimated to be $106.2987 at the end of the first productive year (year 7) of the almond enterprise and $102.2103 [(106.2987)/(1.04)] at the beginning of the year 7 assuming that r=i in all years including the seventh. If, on the other hand, it is assumed that π = 4.8077% during the seventh year, then all CARs in this year must be adjusted. The annual cost of $1,675 becomes $1,755.53 [(1,675)(1.048077)] as in column 1 of Table 10.5, the real annuity of 342.2179 becomes $358.67063, and annual returns are inflated to $2,122.356. The present value at the end of the seventh year (PV(7)) is now estimated to be 111.4092 (column 11) with a value at the beginning of the year of [(111.4092)/(1.09)] 102.2103 (column 10) as before. We can also compute the value of these income streams at the beginning of the first period. This is done using equation 10.8, which discounts all net returns to the beginning of the first period assuming that inflation occurs only in period 7.

$$PV(0) = \frac{\sum_{k=J+1}^{N} R_k(1+r)^{1-k}}{(1+i)} = \sum_{k=J+1}^{N} R_k(1+r)^{1-k}(1+i)^{-1} . \qquad \textbf{(10.12)}$$

For the almond example this gives a net present value at the end of the 0^{th} period of 80.778 [102.21030/$(1.04)^6$] as reported in column 9. The discounted returns for each year over the entire life of the orchard are reported in columns 5-7 of Table 10.5. These columns allocate preproductive costs to preproductive years and operating costs to productive years. Thus these columns have large negative returns in the preproductive years and much higher net returns in the production years compared to columns 9-11 where returns and costs are zero in the preproduction years. Notice that the net present value of returns in columns 5-7 are the same as those in columns 9-11 (where the preproductive costs are accounted for as an annuity).

Converting to Equivalent Annual Annuity

The final step required to enable comparison of enterprises with unequal lives is to convert each enterprise's NPV to an equivalent annual annuity. An annual equivalent is a constant return which, when summed over the total life of the enterprise, is equal to the net present value of the returns from the enterprise. An equivalent annual annuity is assumed to be received during every year of the enterprise's life, **including all preproductive and productive years.**

The formula used to calculate an equivalent annual real annuity (EAA) is given in equations 2.31, 6.8, and 2B.6 where the numerator is now PV.

$$EAA = \frac{PV}{\sum_{k=1}^{N} (1+r)^{-k}} = \frac{PV}{US_0(r,N)} = \frac{PV}{\left(\frac{1 - \frac{1}{(1+r)^N}}{r}\right)} . \qquad \textbf{(10.13)}$$

This is the real payment made at the end of each of the periods of the enterprise life that has the same present value as the actual return stream calculated in 10.12. Using equation 10.13 for the almond enterprise with an estimated PV of $80.778 results in an EAA value of $5.17077. This means that establishment and production of almonds over a 25-year period yields a return equivalent to $5.17077 at the end of each year of the orchard's life. This value is reported in column 12 of Table 10.5. Because there is inflation of 4.8077% in year 7, the value is 5.41937 in years 7 and beyond. The net present value of this annuity at the beginning of year 1 is 80.77825, as expected. This value of almond returns can be compared to CAR estimates for annual enterprises or to equivalent annuity estimates for other multiyear enterprises.

APPENDIX 10A

Data on Almond Production

Sample Costs per Acre to Establish an Almond Orchard – 1992
California – Northern San Joaquin Valley

Labor rate: $10.72/hr. machine labor Interest rate: 9.0%

$6.70/hr. non-machine labor Trees/Acre: 75

	Costs per Acre					
YEAR	1st	2nd	3rd	4th	5th	6th
YIELD (Meat Pounds/Acre)				500	1,200	1,600
Planting costs:						
Land Preparation - Backhoe (8 holes per hour)	351					
Fumigate - Custom Application	492	3	1			
Disk and Float - 2X	17					
Trees: 75 @ $3.80 (+2 2nd Yr. And 1 3rd Yr.)	285	8	4			
Survey and Plant Trees	75	2	1			
TOTAL PLANTING COSTS	$1,220	$13	$6			
Cultural costs:						
Prune and Train		$19	$25	$37	$74	$74
Irrigate	$33	33	33	33	33	33
Fertilizer and Application	16	21	31	47	57	66
Pest Control - Dormant		29	46	46	46	46
Pest Control - Pinkbud				33	33	33
Pest Control - Shothole/Nutrient		16	19	40	40	40
Pest Control - Worm/Mite	14	19	23	57	57	57
Cultivate - 4X	10	10				
Mow Centers - 7X			33	33	33	33
Weed Control - Winter Strip	67	67	67	67	67	67

Weed Control - Spring Spot			13	13	13	13
Weed Control - Preharvest				10	10	10
Pollination				30	60	60
Miscellaneous Costs	23	23	23	23	23	23
Pickup Truck Use	56	56	56	56	56	56
TOTAL CULTURAL COSTS	$219	$293	$369	$525	$602	$611
Harvesting costs:						
Shake				90	90	90
Pole					7	9
Sweep				7	16	21
Hand Rake				2	2	2
Pickup and Haul				26	63	97
Hull and Shell				25	60	80
TOTAL HARVEST COSTS				$150	$238	$299
Interest on operating capital @ 9%	53	9	10	22	27	28

U.C. Cooperative Extension

	Costs per Acre					
YEAR	1st	2nd	3rd	4th	5th	6th
Overhead costs:						
Office Expense	30	30	30	30	30	30
Almond Board of CA Assessment Fee				11	27	36
Leaf Analysis Fee	5	5	5	5	5	5
Property Taxes	61	61	61	61	61	61
Equipment Insurance	31	31	31	31	31	31
Investment Repairs	4	4	4	4	4	4
TOTAL OVERHEAD COSTS	$131	$131	$131	$142	$158	$167
TOTAL CASH COSTS	$1,560	$383	$453	$765	$935	$1,006
INCOME FROM PRODUCTION				$500	$1,200	$1,600
NET CASH COSTS FOR THE YEAR	$1,560	$383	$453	$265		
PROFIT ABOVE CASH COSTS					$265	$594
TOTAL ACCUMULATED NET CASH COSTS	$1,560	$1,943	$2,396	$2,661	$2,396	$1,802
Depreciation:						
Buildings	14	14	14	14	14	14
Flood Irrigation System	19	19	19	19	19	19
Fuel Tanks & Pumps	4	4	4	4	4	4
Shop Tools	7	7	7	7	7	7
Equipment	44	44	44	44	44	44
TOTAL DEPRECIATION	$88	$88	$88	$88	$88	$88
Interest on investment @ 4%						
Buildings	9	9	9	9	9	9
Flood Irrigation System	10	10	10	10	10	10
Fuel Tanks & Pumps	2	2	2	2	2	2
Shop Tools	3	3	3	3	3	3

Land @ $5263/acre	211	211	211	211	211	211
Equipment	12	12	12	12	12	12
TOTAL INTEREST ON INVESTMENT	$247	$247	$247	$247	$247	$247
TOTAL COST FOR THE YEAR	$1,895	$718	$788	$1,100	$1,270	$1,341
INCOME FROM PRODUCTION				$500	$1,200	$1,600
TOTAL NET COST FOR THE YEAR	$1,895	$718	$788	$600	$70	
NET PROFIT ABOVE TOTAL COST						$259
TOTAL ACCUMULATED NET COST	$1,895	$2,613	$3,401	$4,001	$4,071	$3,812

Source: University of California, Cooperative Extension, Department of Agricultural and Resource Economics.

APPENDIX 10B

Allocating Preproductive Costs with the User Cost Method

Managers frequently face decisions on when to replace depreciable assets, but it is a controversial topic. The basic problem is that all of the standard methods in use require a forecast of the price of the output that is produced while using the asset, unless output is constant and unaffected by age of the asset. For example, in the case of a peach orchard, the usual discounted cash flow methods require a forecast of peach prices for each year over the expected life of the trees. Controversy arises over the validity of price forecasts no matter how those forecasts are made. The method presented here avoids this problem by not using price forecasts, but instead only known historical cost data. The method can be attributed to the article by Harold Hotelling. The criterion for replacement is "minimum unit cost." In other words, the age of replacement is chosen so as to minimize the cost of production per unit of output. An application to cling peach orchards is given here to explain and illustrate the method. Sequential fine tuning of the replacement decision in the face of price uncertainty is also provided.

Replacement Decision Method

All replacement decision methods begin by evaluating the expected productivity of an asset over its life. The typical yield pattern by age of trees for late maturing peach varieties is given in 10B.1, which was constructed from the California Cling Peach Advisory Board's "Orchard Production Survey, 1994-95." Yields are zero the first two years after planting and then increase steadily, reaching a maximum of 22 tons in the ninth year of age, where yields start declining steadily to about 12.5 tons by age 25. Initial establishment of the orchard requires quite a large outlay that is followed by two years without revenue and some additional costs before revenues begin, which makes peach production a long term, capital-intensive investment. An important economic question is: What is the optimal age at which the orchard should be replaced, or the land devoted to another use? This question is answered below by applying Hotelling's minimum unit cost criterion.

Investing land and capital in the production of an orchard crop is intended to generate a cash flow from that crop. A large part of the investment's total cost is the interest expense associated with the money tied up in land and capital. The primary nonland investment is establishment costs incurred before the trees begin to bear fruit. Cash flow costs are annual outlays associated with caring for the trees, cultural costs, and harvest costs. The general idea behind the unit cost criterion for replacement is to calculate the cost per unit of output (peaches in this example) for a given replacement age, and through a search over various replacement ages, choose the age that has the smallest cost associated with it. If all costs (including fixed costs, management, and such nebulous things as a margin for risk that do not affect optimal replacement age) were taken into account, a price per unit of output just equal to this minimum cost, which will now be referred to as "unit cost," would allow the firm to just break even in the production of peaches. Thus, the objective is to choose the replacement age which minimizes the cost per unit of output and, therefore, obtain the largest profit margin.

The value of land is treated as the initial investment cost, and this cost is recovered at the end of the orchard's economic life. Establishment costs for the orchard are put into the first year's annual cost category. Establishment costs could be included with land value, but then their depreciated value of zero at replacement would need to be recognized. Salvage value of the orchard investment is the net market value of the old trees, which could be either positive or negative, plus the value of land which would suffer no depreciation over the life of the orchard, with few exceptions.

It is necessary to define some special notation in order to make the definition of the minimum unit cost criterion for replacement unambiguous. The following definitions will be used, where the subscript j on a letter denotes the j[th] year in the life of the asset:

C_j = annual cost associated with an asset of age j
Q_j = quantity of output from the asset at age j
r = replacement age
V_0 = initial investment cost of the asset
V_n = salvage value of the investment if replaced at age n
r = the real rate of interest expressed in decimal form.

A dollar value received t years in the future is transformed into an amount that is comparable to a dollar received now by dividing the future amount by $(1+r)^t$. For example, with an interest rate of five percent, \$10 received two years from now would at present be worth $\frac{\$10}{(1+r)(1+r)} = \frac{\$10}{(1.05)^2} = \$9.07$.

The unit cost equation described earlier in words can now be written as

$$\frac{uQ_1 - C_1}{(1 + r)} + \frac{uQ_2 - C_2}{(1 + r)^2} + \ldots\ldots \frac{uQ_n - C_n}{(1 + r)^n} + \frac{V_n}{(1 + r)^n} = V_0 .$$

Solution of the above equation for the unit cost variable u gives the formula,

$$u = \frac{V_0 - \frac{V_n}{(1 + r)^n} + \frac{C_1}{(1 + r)} + \frac{C_2}{(1 + r)^2} \ldots\ldots + \frac{C_n}{(1 + r)^n}}{\frac{Q_1}{(1 + r)} + \frac{Q_2}{(1 + r)^2} + \ldots\ldots + \frac{Q_n}{(1 + r)^n}} .$$

One obtains the minimum unit cost replacement age by searching over a set of values for n that is expected to include the optimal replacement age, and the smallest value of u indicates the optimal choice of n for replacement age. The procedure is illustrated below in a cling peach orchard example.

Cling Peach Orchard Replacement Results

Estimates of the costs and physical relationships summarized above were made for a small peach orchard in the Southern San Joaquin Valley. Estimates of annual costs and peach yields (tons/acre) in relation to age of the orchard are given in Table 10B.1, columns 2 and 3, respectively. Salvage value of the orchard itself is approximated as zero (excluding the land value at that time). Therefore, salvage value V_n in the formula for unit cost is the value of land at the time of replacement, which is taken to be equal $5,500, the same value used for the investment cost of land at the time the initial orchard is planted. The real rate of interest used is 5%. This is all the data that is needed to apply the unit cost criterion for optimal replacement of the peach orchard.

The cost of producing a ton of peaches is given in the last column of Table 10B.1 for each replacement age. The lowest is achieved with replacement at 15 years, and this result does not change if land value is between $2,000 and $10,000 per acre. With land price at $500 to just under $2,000, the optimal replacement age is 14 years, while a land value of $25,000 calls for replacement at 18 years. The economic intuition underlying this result is that the high interest costs accompanied by low yields early in the yield cycle must be compensated by holding the orchard longer even though yields are decreasing considerably between ages 15 and 18. Modest changes in the salvage value of the old orchard, up or down by $500, did not alter the replacement age from 15 years.

As expected, the best replacement age was quite sensitive to interest rate changes, as shown in Table 10B.2. For example, the best replacement age changed from 15 to 17 years when the interest rate was doubled from 5% to 10%, and another doubling of the rate from 10% to 20% increased the optimal replacement age to 22 years. But moving the interest rate down from 5% to 0% only lowered the replacement age from 15 to 14 years. Incidentally, a zero interest rate in the formula for unit cost converts the unit cost formula into average cost per unit of output, which is quite an intuitive criterion when the business does not have to bear any interest costs, either explicit or implicit, through opportunity cost of the farm's own funds.

Although the optimal replacement is changed by altering the interest rate and other economic factors involved in unit cost measurement, replacing the orchard three years too early or late increases cost per ton of peaches by only a dollar or two (see the last column in Table 10B.1). Mistakes in the direction of too short a period are more costly than keeping the orchard too long, e.g., replacing the orchard after 25 years (a 10-year error) gives a cost of $98 per ton instead of the minimum of $492, while replacement at age 10 (a 5-year error) gives the same cost of $498 per ton. Since the unit cost of peach production is so insensitive to modest variations in replacement age similar to those estimated here, peach producers should feel comfortable using 15 years as a "rule of thumb" replacement age for their orchards.

The insensitivity of unit cost to delaying the replacement age of a peach orchard by as much as even ten years from the least cost age provides the producer great flexibility to delay replacement if peach price expectations are relatively high for the near future. Replacement of an acreage of peaches results in almost zero production for three years, making it economically attractive to postpone replacement until price expectations decline to what is thought of as more nearly normal levels. This observation also suggests that a risk averse producer would be included to diversify by synchronizing various aged stands to provide a fairly constant supply of fruit. Nevertheless, the astute producer would probably deviate from the nearly even aged stands goal to exploit short-run output price dynamics. Data on aggregate acreage response to changing prices by cling peach growers suggest a tendency to diversify by avoiding heavy concentrations of trees of the same age.

TABLE 10B.1 Costs and Yields by Age

Age	Annual Costs (dollars)	Yield (tons/acre)	Unit Cost (dollars)
1	1,972	0	----
2	469	0	----
3	4,372	9.4	841.01
4	6,020	14.0	611.47
5	8,022	17.5	555.00
6	9,106	19.9	529.24
7	9,877	21.4	516.09
8	10,113	22.0	507.74
9	10,152	22.1	502.21
10	10,074	21.9	498.45
11	9,877	21.4	495.91
12	9,606	20.7	494.24
13	9,326	20.0	493.17
14	9,051	19.3	492.53
15	8,736	18.5	492.22
16	8,648	17.8	492.67
17	8,244	17.1	492.90
18	7,999	16.4	493.34
19	7,825	15.7	494.08
20	7,619	15.1	494.93
21	7,339	14.6	495.63
22	7,087	14.0	496.34
23	6,834	13.5	496.98
24	6,635	13.0	497.63
25	6,478	12.6	498.29

TABLE 10B.2 Optimal Replacement Ages

Interest Rate	0	.05	.10	.15	.20
Optimal Age	14	15	17	18	22
Unit Cost ($)	471	492	518	548	586