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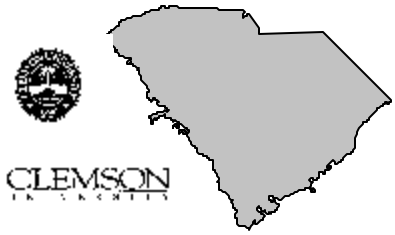

HANDLING DURABLE AND NONDURABLE FARM INPUT DECISIONS USING A SINGLE THEORETICAL FRAMEWORK

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HANDLING DURABLE AND NONDURABLE FARM INPUT DECISIONS USING A SINGLE THEORETICAL FRAMEWORK

ABSTRACT

Students in economics are taught that the optimal usage of a nondurable input occurs when the value of its marginal product (VMP) equals its marginal cost (MC). However, this fundamental condition has rarely been extended to durable inputs. Even advanced textbooks have done little to compare and contrast the optimality conditions for durables versus nondurables. This paper outlines and compares a common VMP-MC decision framework for (1) nondurables in a single-period time horizon, (2) durables in a finite planning horizon, and (3) durables in an infinite planning horizon.

INTRODUCTION

In introductory production economics, students are taught that the optimal level of a nondurable input occurs when the value of its marginal product equals its marginal cost, VMP = MC. In more advanced courses, students see that this optimality condition can be extended to encompass durable inputs. However, a valid and comprehensive extension requires a precise delineation of the conditions necessary to accommodate the realities regarding nondurables and durables.

Two realities must be dealt with. First, durables are lumpy and their productive services tend to be non-divisible. The quantities of their services often cannot be precisely quantified and assigned to the production of a particular product in a given time period. Second, the relevant investment and production horizon for durables may not be constant, or even finite. Consequently, investment and production decisions cannot adequately be viewed in a timeless fashion. To be more realistic, time must be explicitly considered in the analysis. For more background on theory underlying the handling of these two realities, see Lutz and Lutz [8, pp.3-8].

The objective of this paper is to outline the salient features of a single, fundamental VMP-MC framework that can be employed, in a limited sense, to solve optimal investment and allocation decisions for both nondurable and durable inputs. Marginal optimality conditions for three input (asset) situations are delineated and compared: (1) nondurables in a single-period time horizon, (2) durables in a finite (N-period) horizon, and (3) durables in an infinite horizon. Due to space limitations, the analysis is confined to pre-tax situations.

For durable inputs, the problem situation is not new. But it has not been completely solved, even theoretically. Almost half a century ago, Lutz and Lutz [8, pp. 3-15] devoted most of their first chapter to discussing its nature and its evolution in the literature. More recently, Robison and Barry [10] devoted a large part of their text to its solution. They indicate [10, pp. 1-2] "... the link between timeless (static) profit functions and PV [Present Value] models will be explicitly established." However, they do very little, at least explicitly, in the way of defining and employing a derived VMP-MC framework.

DEFINITIONS

Before comparing and elaborating on the three input situations listed above, some common problems of ambiguous definitions and consequent incorrect usage of fundamental terms must be considered. To avoid

ambiguity, we define and classify inputs and their productive services in Table 1.

Table 1. Definitions of Terms.[a]

Production	*Production* is the process of combining and coordinating materials and forces (inputs or productive services) in the creation of some output of a specified product. A *production function* is a specification of the various technical production possibilities faced by the firm. The function specifies the maximum output in physical terms for each level of the inputs.
Durable Input	An input (asset) that will provide productive services to the firm for more than a single time period, e.g., a farm tractor or grain bin.
Nondurable Input	An input (asset) that will provide productive services to the firm for a single time period, e.g., animal feed or crop fertilizer.
Fixed Input Service	Occurs whenever an input has productive services that do not vary with the amount of output produced. Thus, in an *ex post* sense, an input is fixed in the productive process if/when its services have already been expended (sunk). In an *ex ante* sense, three conditions determine fixity: (a) length of the decision-maker's planning horizon, (b) the particular time point on the horizon, and (c) feasible, alternative productive uses of the input.
Variable Input Service	Occurs whenever an input has productive services that do vary with the amount of output produced. Thus, an input's services are variable if/when the costs of the service are expected to vary with the quantity of output produced; otherwise they are fixed.

[a] Definitions and explanations in this table are adapted, in part, from Beattie and Taylor [2], Carlson [3], and Lutz and Lutz [8].

As Grant [5] first explained in 1930, the nondurable-durable distinction is straightforward. It is strictly physical in nature. Further, as Carlson explained [3, pp.104-105] "(t)his distinction...must not... be confounded with the distinction between fixed and variable." Even so, modern texts sometimes incorrectly equate durables with fixed inputs, e.g. [10, pp. 55, 424].

This ambiguity could be avoided if analysts would distinguish between fixed and variable inputs and also distinguish between durable and nondurable inputs. As the Table 1 definitions imply, whenever the decision-maker is considering a multi-period time horizon, a durable input can give rise to either fixed or variable services. Likewise, a nondurable input can give rise to either fixed or variable services. What is fixed and what is variable is essentially a function of the decision-maker's mind. The decision-maker is in a planning, not a historical mode. So, the three *ex ante* conditions listed in Table 1 determine fixity (or variability) of both nondurable and durable input services.

NONDURABLES IN A SINGLE PERIOD

This is the simplest and most limited of all input investment/production situations. It is the only decision situation covered in most introductory production textbooks (e.g., [4]). Unfortunately, it also is the only one covered in some advanced production texts (e.g., [2]).

In a single-period time horizon, the optimal amount of the ith input for i = 1, 2, ..., k variable inputs that should be employed by the firm in a certainty environment occurs when

$$VMP_i = C_i + rB_i \quad , \tag{1}$$

where VMP_i denotes the input's value of marginal product; C_i denotes the opportunity marginal cost (often designated as the operating cost) of the ith input; B_i denotes the amount of the i^{th} nondurable input acquired at the beginning of the time period (t = 0); r denotes the applicable periodic interest rate; and the quantity rB_i denotes the interest on the operating cost due to the ith variable input during the period.

Adopting the logic set forth by Carlson [3, pp. 14-15] and by Lutz and Lutz [8, pp.5-6], both the set of durable (A) and nondurable (B) inputs are acquired at the beginning of the time period. Separating rB_i from the other operating costs, though not commonly done, is consistent with the separate estimation of "interest on operating costs" in farm enterprise budgets.

Each marginal product (MP) is determined by the single-period production function, which in its simplest form has a single product, k variable inputs, and j fixed inputs. The j fixed inputs comprise what is commonly defined as the firm's "plant." In this situation at t = 0, all of the k variable inputs are nondurable and all of the j fixed inputs are durable (see Table 1). This is convenient but often unrealistic.

By definition, none of the input services of the k nondurables lasts for more than a single period. The quantity of a nondurable that the firm should acquire equals the quantity that should be used to achieve allocative optimality. In reality, however, it is entirely possible that the optimal quantity of a nondurable input (B_i) that should be acquired (and used) equals zero. That is, C + rB could exceed VMP for every amount of the input that might be used. As a practical example, consider the low MP that would occur when corn is fertilized by zinc, an element that is not deficient in most soils.

DURABLES IN A FINITE PLANNING HORIZON

In more advanced courses, students are taught that, in addition to employing nondurables in the production process, the firm also invests in and uses durable inputs, such as grain combines. Limited attention has been given in the literature to the parallels and differences with the optimality conditions for nondurables. The lack of attention is not new, having been noted by Carlson [3, pp.103-09] and by the Lutzes [8].

In a certainty environment, the optimal investment in and use of a durable, like a nondurable, occurs when the input's VMP equals its MC. More precisely,

$$VMP_{ijt} = C_{ijt} + \Delta A_{ijt} + rA_{ijt} \quad , \tag{2}$$

where VMP_{ijt} denotes the value of the ith durable (and, in this finite horizon, variable) input's production of product j in time period t. The right side of (2) contains three MC components - - not the single component one commonly sees written in a nondurable optimality equation, or the two right-side components shown in expression (1). Specifically, C denotes the opportunity marginal cost of the ith durable input during period t; A represents the stock value of the durable input at the beginning of the investment/ production period; ÄA represents any value change (depreciation or appreciation) during period t; and rA denotes the opportunity interest cost on the firm's investment in A during the period.

Theoretically, each MP is determined by an N-period production function. At the beginning of each period in the horizon, all nondurable inputs are expected to give rise to variable services. Likewise, all durable inputs

that are subject to being replaced during the period also are expected to give rise to variable services. Only the durable inputs that are not expected to be replaced during that period (such as land) are regarded as fixed at the beginning of each period in the finite horizon.

Each of the three right-side MC components should be valued as an opportunity cost, not as an acquisition (historical) cost. This is a point explained by Johnson and Pasour, Jr. [6], Perrin [9], and Johnson and Quance [7]. In these writings, however, the meaning of "asset fixity" is not necessarily the same as the meaning of a fixed input (asset) as defined in Table 1. Rather, it pertains to a situation where the acquisition price for a new (replacement) durable input is greater than the present (stock) value of marginal product of the current (like) input; but, at the same time, this value exceeds the salvage (sales) price of the old, current input. Thus, a firm in an "asset fixity" mode is, in a sense, stuck with continuing to use the old asset, rather than entering into any replacement investment of the durable input in question.

Whenever the decision-maker is interested in the acquisition (investment) of a new durable, the focus usually is on selecting the correct time interval (t) that allows the equality in expression (2) to exist. Alternatively, if the decision-maker is interested in the optimal level of durable input production usage, the focus, in effect, shifts to the subscript i. As Lutz and Lutz [8] emphasize, it is difficult, if not impossible, to link particular units of input to particular units of output in the specified period, t. "All that we can say is that all the inputs embodied in the durable good [asset] are jointly responsible for the whole stream of output [over several periods] [8, p. 7]."

DURABLES IN AN INFINITE PLANNING HORIZON

Identical Durables

When the decision-maker's planning horizon extends beyond the economic life of the currently owned durable input, it is more precise to consider an infinite time horizon. This facilitates the explicit expression of expected earnings from the series of replacement inputs. In other words, it allows for the consideration and measurement of intertemporal opportunity costs. The VMP-MC optimality equation can be written as a logical extension of expression (2), viz.,

$$VMP_{ijt} \;'\; C_{ijt} \;\%\; \ddot{A}A_{ijt} \%\; rA_{ijt} \%[r][1\&(1\%r)^{\&N}]^{\&1}[PV(N)] \qquad (3)$$

where VMP and the first three MC terms of the right side are identical to the specifications delineated for equation (2) for durables in a finite horizon.

The latter multiplicative, compound term models the intertemporal opportunity costs, valued at the same time point(s) in the horizon as the finite-horizon terms. In particular, r denotes the appropriate periodic opportunity interest rate; N denotes the identical, replacement time interval that is to be determined; $[1-(1+r)^{-N}]^{-1}$ denotes the present value of a $1 perpetual annuity paid at the beginning of each and every N periods; $[r][1-(1+r)^{-N}]^{-1}$ denotes the ordinary annuity certain with a present value of $1 (i.e., the capital recovery factor); and [PV(N)] denotes the present value for an N-period replacement interval for the identical ("new") durable replacement input under consideration. More precisely,

$$PV(N) = \sum_{t=1}^{N} (VMP_{ijt} - C_{ijt})(1+r)^{-t} - A_o + A_N (1+r)^{-N} \qquad (4)$$

where VMP - C denotes the periodic stream of expected annual opportunity operating incomes for the replacement input (asset), referred to by the Lutzes [8, p. 12] as "quasi-rents;" A_0 denotes the value at t = 0 of the investment in the durable replacement asset; A_N denotes the value of the asset at t = N; and $(1 + r)^{-t}$ and $(1 + r)^{-N}$ are the respective discount factors.

One can describe numerous practical examples of intertemporal opportunity costs in an effort to illustrate why they should not be ignored. For example: (a) the cost of continuing to own and use a stream of a particular model of farm pickup trucks for, say, eight years as opposed to owning and using them for seven years, or (b) the cost of continuing to own and feed steers for, say, 150 days as opposed to owning and feeding them a more efficient 120 days. It could be argued that the magnitude of such intertemporal opportunity costs is inconsequential. But this is an empirical contention that is missing from Johnson and Pasour [8]. Clearly, their durable resource adjustment rule, either inadvertently or by design, fails to consider intertemporal opportunity costs – the latter term in expression (3).

Non-identical Durables

For some problems the assumption that the input should be replaced with another of its own kind, having an identical time pattern of cash flows, is too simplified. Rather, the decision-maker must turn to a non-identical series present value model such as expression (6) in Perrin [9] or (5) in Bradford and Reid [1]. Further, when desiring to make endogenous the intertemporal opportunity costs attributable to factors such as capital constraints, machine capacity, or the lumpiness of machines (or similar lumpy inputs), one would be well advised to rely upon a comprehensive programming-future value model.

The valid marginal optimality expression of acquisition and usage decisions in the non-identical durable input case depends on the expected time pattern of technical and market parameters. It can be very unwieldy and virtually impossible to write in a VMP-MC context. Robison and Barry [10, pp. 525-537] present the mathematics when it is assumed that the durable series are related to each other by a multiplicative factor, 1 + h, where h is the expected rate of periodic technological change. Perrin [9, pp. 62-63] presents an expression and short discussion when only a one-time change in technology is expected. In appearance, it is similar to expression (3), but the decision-maker must recompute the value of PV (N) at the beginning of each and every successive production period. In short, in this complicated, yet realistic, input acquisition and usage situation, the standard VMP = MC is too simple to accommodate all the parameters and their dynamics that deserve to be modeled.

CONCLUDING REMARKS

The objective of this appear will be achieved if the reader understands that adding a durable-nondurable classification to the usual fixed-variable distinction enhances the clarification of the study of the decision making process for investment and production in a multi-period environment. Hopefully, the door has been

opened for re-examining the extension of a VMP-MC optimality framework to the world of durable inputs.

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APPENDIX: THE PERRIN BENCHMARK ARTICLE

Perrin's 1972 article in the *American Journal of Agricultural Economics* on optimal replacement-investment decision modeling remains widely regarded by many applied economists as the conceptual benchmark for conducting research and graduate teaching in capital investment-replacement. His article deals mostly with identical Challenger modeling and selected applications, both continuous models and their discrete analogs. Marginal analysis optimality conditions are derived from present value models. The two types of models are shown by Perrin (p. 65) to yield equivalent replacement intervals.

The article, notwithstanding its continued widespread acclaim, is really quite limited in scope. Present value and marginal analysis models of non-identical asset replacement are only briefly discussed, and then only for selected replacement situations - - specifically "replacement with technologically improved assets." This appendix first focuses on identical-challenger models and secondly on what may be called two-segment replacement models. More specifically, the appendix deals with (a) limitations and imprecisions in Perrin's treatment of such models, and with (b) extension of such models to handle specific replacement-investment problems other than replacement due to expected changes in technology. Like Perrin's article, certainty of all expectations is assumed. With only minor modifications, all definitions and notation are identical to that employed by Perrin.

The marginal optimizing condition for replacement of a Defender with an infinite series of identical Challengers was shown by Perrin (p. 61) to be:

$$R\,(S) \,\%\, M'\,(S) \;'\; \tilde{n}\, M\,(S) \,\%\, \tilde{n}\, C\,(0,\, S,\, 4) \tag{4}$$

where S is the replacement interval (optimal or nonoptimal) which is selected by the decision maker, R(S) denotes the residual earnings from the asset or project in period S, M(S) is the market (or salvage) value of the asset (project) at the end of period S, M' (S) is the change in the asset's (project's) capital value in period S, C(0, S, 4) is the present value of the infinite stream of residual earnings and capital value changes from the infinite series of Challenger assets or (projects) acquired at age t (time) = 0 and replaced at the end of t = S, and ñ is the appropriate periodic interest rate. Wording of these definitions is modified very slightly from that used in Perrin's article, in order to be consistent with the context of the discussion and contentions of this paper. Specific modifications will be explained as used.

When the series of Challengers are expected to yield residual earnings or capital value changes which differ from the cash flow series for the Defender, but which are identical across the infinite series of Challengers, the marginal maximizing condition was shown by Perrin (p. 63) to be:

$$R(C) \,\%\, M'\,(C) \;'\; \tilde{n}\, M\,(C) \,\%\, \tilde{n}\, C(0,\, S,\, 4) \tag{6}$$

where the optimal replacement age for the Defender is determined to occur at t = C, and the optimal replacement interval of the series of Challengers is expected to occur each and every S periods. This is the marginal condition which can be derived, as Perrin explains, from a two-segment, present value model.

Five points are pertinent regarding a more precise presentation and practical use of these marginal conditions, (4) and (6), above.

Point 1

Values for C(0, S, 4) in (4) and (6) must be optimal present values of the infinite series of identical assets or investment projects. Thus, even though the marginal criterion may be preferred by many economists, perhaps because its terms are easily defined and it appeals to their intuition, when employing any marginal criteria it is still necessary to derive and understand present values of infinite series. To be quite precise, the replacement age (S) of Challengers must be specified as the optimal age. That is, the value for C(0, S, 4) is an optimal value - - a constant insofar as used and interpreted in (4) and (6). Therefore, the clarity of exposition in Perrin's article could have been improved by using S* to denote the optimal replacement age or by using Max C(0, S*, 4), or Min as the case might be. Then, in keeping with this distinction, C(0, S, 4) would denote replacement at any non-optimal age, S.

Point 2

One should realize that determining the appropriate value for C(0, S, 4) for the nonidentical Challenger model, (6), usually is more complex than determining the value of this variable for the identical Challenger model, (4). For model (4) one knows the type of asset for all replacement intervals from t = 0 until t approaches 4. It is identical to the Defender, meaning that the time incidence of cash flows for the infinite series of assets are constrained by the model's assumptions to be identical. For model (6), however, one must select the Challenger asset (or project type). This selection process, of course, could be fairly routine. For example, consider a slightly larger farm machine but otherwise essentially the same as the current machine. More realistically, the selection process, at t = 0, could involve consideration of numerous prospective Challengers. Selection then would entail a prior, separate capital budgeting process - - presumably a comparison of mutually exclusive projects. These qualifications were not discussed by Perrin.

Point 3

Both ñ M(S) and ñ C (0, S, 4) in (4) [ñ M(C) and ñ C(0, S, 4) in (6)] are opportunity costs of postponing the replacement of the Defender. In most parts of Perrin's article the two terms are lumped together into what he refers to as "average opportunity gain associated with the replacement asset." But it seems more instructive or clear to recognize that only the value of ñ M(S) is the traditional measure of opportunity cost, the intra-temporal opportunity cost, sometimes expressed simply as "interest on investment." For example, if an old tractor (Defender) is retained for one more period the foregone interest proceeds on the tractor's resale or trade-in revenues will equal ñ M(S). Then, as Perrin (pp. 61-62) notes, one can discuss why ñ C(0, S, 4) equals the opportunity cost of postponing the earnings which will be forthcoming from the series of Challengers. This intertemporal opportunity cost component often is ignored. Or, at least sometimes it is regarded as inconsequential in magnitude (e.g., Boehlje and Eidman, p. 600). Readers should realize that the consequences of ignoring intertemporal costs can be dire in many real world replacement situations.

Point 4

Perrin's definition of C(0, S, 4) as "the present value of the stream of residual earnings [underlines added] from a Challenger to be purchased at age 0 and replaced at age S by an infinite series of identical Challengers" is ambiguous. More emphatically, a strict interpretation of this wording is at odds with traditional economic capital theory (Lutz and Lutz) and with contemporary literature in financial economics and accounting (Weston and Brigham). Recall that

$$C(0,\ S,\ 4)\ =\ [(1-e^{-\tilde{n}S})^{-1}]\ [\int_0^S R(t)\ e^{-\tilde{n}t}\ dt\ +\ M(S)\ e^{-\tilde{n}S}\ -\ M(0)] \qquad (7)$$

To be precise, residual earnings in any period, t, equals only R(t). In traditional treatments of capital theory, R(t) is known as Q(t) - - the "quasi-rent" addition attributable to an (new or old) investment project. Alternatively, in applied firm management writings Q(t) is known as the "added net returns due to the investment," i.e., the net returns over operating costs. In contemporary financial economics and accounting literature R(t) is usually defined as earnings before depreciation, interest and taxes (EBDIT) or as net operating income plus depreciation (NOI + DEP).

In any event, it is precisely the stream of undiscounted R's that comprises the stream of residual earnings from the asset or project. The other two terms in the second bracketed expression, above, - - $M(S)\ e^{-\tilde{n}S}$ - M(0) - - comprise the capital appreciation (depreciation) in present value units. Hence, the entire second bracket is the expected incremental gain (loss) in wealth, or the expected addition (loss) in the firm's value for each asset or project. Multiplication of the second bracket by the perpetual annuity term - - $[1 - e^{-\tilde{n}S})^{-1}]$ - - converts the infinite stream of projects, which are expected to provide identical undiscounted additions to wealth, to a single present value number.

Possibly Perrin was aware of such definitional and conceptual distinctions when his article was published. Nevertheless, the article itself fails to adequately recognize or delineate such specifics.

Point 5

When discussing the two-segment model, (6), Perrin states (p. 63): "As a practical matter, a decision maker might compute C(0, S, 4) each year using the best data available on the Challenger and compare net returns expected next year from the old asset with ñ [M(C) + C(0, S, 4)]. If net returns from the old asset are larger, he will continue with it for another year at which time an updated comparison is made, and so on, making a decision each year with the best information available at the time." Upon initial reading, this advice may seem obvious, even trivial. But this is precisely the essence of any methodology which will allow researchers (or decision makers) to handle the dynamics of technological change or of inflation (or more importantly to account realistically for changes in relative prices), and to evaluate through time the changing sets of relevant investment projects.

In essence, this methodology is in keeping with the "best-first-move" approach advocated by Modigliani and Cohen (1961). As time and conditions change, expectations regarding technology and market prices are altered. Specifically, the parameters of model (6) must be periodically reestimated.

Relative prices and discount rates must incorporate new information and expectations regarding technology or inflation rates. Inflation must be dealt with whether nominal or real dollar values are used in the model. Of course, the estimated nominal discount rate for Challenger projects could be larger (or smaller) than rates for the current Defender. Smaller rates for the Defender can be justified if the set of Challengers are expected to entail added business risks or to involve more inflation.

Theoretically, infinite-series, present-value counterparts of model (6) may be employed over time to structure and alter the portfolio of the firm's assets. Two decision rules are appropriate for choosing or altering the portfolio. They are: (a) for each set of mutually exclusive projects select the project with the largest net present value (NPV), assuming the firm is maximizing, and (b) for the remaining set of independent projects, including accepted projects from (a), select all projects with net present values $0. Keep in mind that these are NPVs for an infinite series. Replacement decisions, alternatively viewed, are a special type of mutually exclusive investment decision. For each Defender project, when viewed over the infinite horizon the time periods of ownership are mutually exclusive.

These clarifications, in points (1) - (5), will help the analyst handle unequal horizons in comparing investment (or disinvestment) in a set of independent projects. Also, assuming the optimal debt-equity ratio is known, or can be estimated, the optimum portfolio can be specified. In reality, of course, the optimal capital structure could depend upon the portfolio which is selected, and conversely. One must admit that, when using marginal analysis, capital funds constraints either are ignored or addressed in a very implicit manner. Finally, questions of how to select "production activities" (as opposed to "investment activities") across time periods in the horizon are subsumed within the investment choices. These sort or problems provide researchers with legitimate rationale for building more complex models. The present value approach by itself may be viewed as too partial in scope.

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