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The Usefulness of Accounting Profit Data:

A Comment on Fisher and McGowan

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Bureau of Economics

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In a recent AER article, Fisher and McGowan (henceforth F&M) claim to have shown that "there is no way in which one can look at accounting rates of return and infer anything about relative economic profitability or, a fortiori, about the presence or absence of monopoly profits." In addition, they attempt to link this extremely negative conclusion to the profit-concentration literature: "The literature which supposedly relates concentration and economic profit rates does no such thing".

We will show that F&M had little basis for reaching these conclusions. The examples they present in support of their assertions are flawed and do not reflect central tendencies. The implicit conceptual framework for the theorems and proofs is so limited that their analysis, even if correct, does not justify their conclusions. And finally, they ignore substantial evidence that accounting profits do, on average, yield important insights into economic performance.

I. Analytical Errors.

F&M make several errors in their analysis. First, their calculations for the rate of return on end of year assets are incorrect. Second, their correspondence between continuous and discrete time is incomplete and misleading. Third, they inaccurately cite data from the Economic Report of the President.

F&M's end-of-year asset analysis suffers from either a programming error or a very strange definition of end-of-year assets. In comparing asymptotic accounting rates of return using beginning-of-year assets with those using end-of-year assets (Tables 2, 3, 5), F&M show the former rates as being greater than or equal to the latter.[1] Such a relationship contradicts common perceptions and is inconsistent with the results in their Table 1. If there is depreciation, end-of-year assets must be less than beginning-of-year assets; consequently, if the same accounting profit value is divided by the two asset values, the end-of-year accounting rate of return must be larger than the beginning-of-year accounting rate of return.

Table 1 in Appendix A reproduces F&M's Table 2, but with the correct definition of end-of-year assets.[2] These data yield three insights. First, there is a significant difference between the correct numbers and those reported by F&M. Therefore, their end-of-year asset results, with the exception of Table 1, should

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[1] In general, end-of-year profit rates in F&M's tables are just equal to the corresponding beginning-of-year rate divided by (1+g), where g is the growth rate.

[2] Only straight-line and sum-of-years' digits depreciation method results are given. F&M did not give sufficient information to permit us to distinguish among the many types of declining balance depreciation schedules.

be discarded. Second, the range of accounting rates of return is even larger than their original results indicated. Correcting this error actually enhances their illustrations. Third, the difference between beginning-of-year accounting rates and end-of-year accounting rates is also greater than F&M's original work suggests.

F&M's analysis of end-of-year assets, even when correctly calculated, is still incomplete and misleading. They show in the appendix that if the growth rate is equal to the rate of return, then the asymptotic accounting rate of return will equal the internal rate of return. In the text, on the other hand, they show by demonstration that the relationship holds for only accounting rates of return which use beginning-of-year assets as the denominator. They explicitly note that the relationship does not hold if end-of-year assets are used. The implication is that the standard practice of measuring assets as of the end of the period is incorrect; even if economic depreciation were used to calculate accounting profits, wrong rates of return would be produced. Their conclusion rests on a faulty transition from the continuous case in the appendix to the discrete analysis in the text, and on inconsistent definitions of the three rates.

The continuous time results derived in F&M's appendix hold in discrete time for accounting profit rates defined with beginning-of-year assets as the denominator, if the growth rate and internal rate of return are defined in beginning-of-year terms. However, it also holds for accounting profit rates defined with end-of-year assets as the denominator, provided the growth rate and internal rate of return are defined in end-of-year terms. In fact, it holds for any convex combination of beginning- and end-of-year assets, subject to the requirement that the profit rate, growth rate and internal rate of return are all consistently defined.[3] Part 1 of Appendix B contains a proof of these assertions.

Table 2 in Appendix A further illustrates this point. In this table, the growth rate and the internal rate of return definitions are consistent with profit rates defined in terms of end-of-year assets. The economic rate of return is again set equal to 15 percent. The accounting and economic rate of return are equal at a growth rate of 15 percent for only the return on end-of-year assets. For growth rates higher (lower) than the economic rate of return, the accounting rate of return on end-of-year assets underestimates (overestimates) the economic rate of return. For the range of growth rates used in the table, the return on beginning-of-year assets tends to underestimate the economic rate of return except for long delay, low growth rate

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[3] In some basic sense, it appears that assets and other relevant variables should probably be measured at mid-year instead of either the beginning or the end. Investment, like cash flow, is essentially a continuous variable. Some investment projects are started at the beginning of the year, and some are started at the end, but every point in the period is also a potential candidate for the starting point. In the absence of specific information to the contrary, the mid-point should provide a better central tendency measure than either end-point. For a justification of this observation, see Part 2, Appendix B.

cases. Following F&M's logic, one would conclude from this single illustration that return on end-of-year assets is clearly a better measure of economic rate of return than return on beginning-of-year assets.

There is only one instance in which F&M attempt to link their examples to real world central tendencies and in this case they simply cite the wrong data. F&M use 15 percent as the value of the economic rate of return, claiming that this was the average accounting rate of return for manufacturing in 1978. They note that their analysis is for rates of return to total assets, not for rates of return to equity. The 15 percent value, however, is for return to equity only; the accounting rate of return to total assets was 7.8 percent in 1978 (Quarterly Financial Report, 1979, First Quarter). They claim that the choice of a rate of return is immaterial, since their conclusions would not be affected if some other rate were used, though they note that, all else equal, "... a lower economic rate would reduce the range of accounting rates of return" (fn. 13, p. 85). In fact, as Table 3, Appendix A illustrates, the reduction in the range is fairly substantial both in absolute and relative terms. This table reproduces F&M's Table 2, except that an economic rate of return of 7.8 percent is used instead of 15 percent, and the set of growth rates is centered on 7.8 percent. For the accounting rate of return on beginning-of-year assets, the maximum deviation from the economic rate of return is 3.9 in Table 3, Appendix A versus 10.9 in F&M's Table 2 or 50 percent versus 73 percent of the economic rate of return. Since F&M purport to be saying something about the deviation between accounting and economic profits in the real world, reasonably accurate values are important.

II. The Correct Index of Profitability

Two major problems with F&M's analysis are that they do not put it in the context of a profit maximizing model and they fail to distinguish marginal from average rates of return by not allowing differences in the cash flow pattern across investment projects. Only by ignoring these considerations can they make the absurd claim that "... the economic rate of return is the only correct measure of the profit rate for purposes of economic analysis."

The appropriate measure of profitability obviously must depend on the context in which it is employed. If the analysis involves a study of investment behavior, then clearly the marginal economic rate of return is the correct profit measure. It is not the correct measure when studying monopoly power, as F&M would have discovered had their work been based on a profit maximizing model of oligopoly.

The basic reference here is Bain (1951), the first study in which a test of the profits-concentration relation was reported. Before reporting his empirical results, Bain clearly described his conceptual framework:

> Average excess <u>profit rates on sales</u> should thus be higher with than without monopoly or effective oligopolistic collusion. This prediction evolves into one that there will be larger profit rates with high seller concentration than with moderate or low seller concentration if we posit a systematic association between the probability of effective collusion and the degree of seller

> concentration within an industry. A tentative hypothesis is herewith advanced to that effect. Given this, we arrive at the hypothesis that there will be a systematic difference in average excess _profit rates on sales_ between highly concentrated oligopolies and other industries. (emphasis added)

The ratio of profits to sales is related to the Lerner index of monopoly power. They are the same if marginal cost equals average cost.[4]

With this conceptual model as his starting point, Bain then presented algebraic steps and assumptions by which the economic profit to sales ratio could be translated into the ratio of accounting profits to stockholders' equity. In his empirical work he used the latter ratio, though he reported that he had repeated the statistical tests for the ratios of excess profits to sales and accounting profits plus interest expense to total assets, with the same general results. Many later studies have followed Bain in using one of the asset rates without paying much attention to his conceptual framework.

In recent years several contributions have been made which expand on the conceptual framework for the profits-concentration empirical work. Cowling and Waterson (1976), Gollop and Roberts

[4] Even if marginal and average costs are not equal, structure-profit analysis is still manageable. One approach is to incorporate into the analysis the elasticity of the average cost function, which permits substitution of a simple function of average cost and elasticity for marginal cost, with the result that an equilibrium equation with the profit/sales ratio as the dependent variable may be derived. The average cost elasticity is then one of the variables which determines profitability, and variables which are expected to explain it may be included in the analysis. For such a development, see Long (1982).

(1979), Dansby and Willig (1980), Long (1982) and Martin (1983) have demonstrated that the Lerner index, price minus average cost divided by price, is a measure of monopoly power which may be derived from an optimization exercise in long-run equilibrium oligopoly models that include a conjectural variable. This conceptual work provides additional support for the profit-concentration literature, particularly the studies which have used profits/sales as a dependent variable.

There is a second serious problem with using profit/assets as a measure of monopoly power. The justification for using it is that it approximates the rate of return on investment. But which investment, marginal or average? F&M ignore this question by assuming all investments have the same cash flow, therefore marginal and average are equal. In general, however, the marginal and average investments will differ. If profit/assets is meant to approximate the marginal return on investment, then it tells us nothing about the degree of monopoly power. Every firm, whether competitive or monopolistic, invests until the risk adjusted return on the last investment equals the cost of capital. Under the standard assumption of a constant cost of capital, every firm will in equilibrium have the same marginal return on its investment. Differences in the marginal rate of return will only reflect a temporary disequilibrium, which could occur in either a competitive or monopolistic industry.[5]

If profit/assets are meant to approximate the average rate of return on capital other difficulties arise. The most serious problem is, of course, that economic theory has little to say about average returns. They are not what firms maximize, they are not derived from first order conditions, and they are not equated on the margin. Furthermore, there is no guarantee that the average return on capital will be zero in a long run competitive industry. Assume, for example, a decreasing returns Cobb-Douglas production function with two inputs, capital and labor. In addition, assume a license fee is required to operate in the industry, with no restriction on the number of licenses given.[6] These conditions yield the standard U-shaped average cost curve. In the long run, entry will force the price equal to the minimum point on the long run average cost curve. The Cobb-Douglas production function, however, implies a declining marginal productivity of capital curve, which yields the standard declining marginal efficiency of capital schedule. The average

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[5] The constant cost of capital assumption is probably inaccurate. A more reasonable assumption would be that a monopolist has a lower cost of capital because it can use the monopoly profits as a source of internal funding and its investments are likely to be less risky. But, this then implies that a monopolist will have a <u>lower</u> marginal rate of return on its investment.

[6] In accounting terms, the license fee would be considered a current expense and not part of the capital stock provided the contract period was sufficiently short, e.g., monthly, quarterly, or even annual.

productivity of capital lies above the declining marginal productivity curve, implying that the average return on capital is positive, despite the fact the firm is making zero profits.

Thus, F&M had little theoretical justification for focusing on profits/assets as a measure of profitability, particularly if they wanted to say something about monopoly power. We do not wish to imply that as a practical tool the ratio of profits to assets is a meaningless measure. It may be a good measure for investment analysis.[7] Even for identifying monopoly power, this measure obviously reveals some information.

If average returns to sales are higher for monopolistic than competitive firms, then, cetaris paribus, average returns to capital will also be higher. Though the theoretical connections of profits/sales are stronger for structure-performance analysis, empirical studies which use profits/assets as the dependent variable are useful because of the association between profits/assets and profits/sales.

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[7] See Stigler (1963) and Feldstein and Summers (1977) for illustrative uses. In both of those studies the authors explicitly considered the impact of alternative depreciation schedules on measurements of the rate of return on assets. Even though they recognized the same kinds of problems to which F&M refer, they concluded that the data were useful for their investigations.

III. The Validity of F&M's Examples

Even though F&M's analysis is inaccurate and incorrectly applied, it is still useful to examine what sort of inferences can be drawn from their theorems and examples. The theorems show that accounting profits will not equal economic profits except in special circumstances. However, for most uses of accounting profits, <u>equality</u> with economic profits is not necessary. It is sufficient that accounting profits act as a reasonable proxy for economic profits. The examples employed by F&M illustrate that in some cases the differences between accounting and economic profit can be fairly large. Other examples can just as easily be devised, of course, for which the differences are immaterial. The relevant questions are which examples are more representative of the population as a whole and whether the measurement errors introduce bias in statistical studies?

Work by Stauffer (1971) sheds some light on these issues. He estimated economic profit for nine industries in which large differences between accounting and economic profits were likely. These were industries with a substantial amount of long-lived assets, R&D expenditures, advertising expenditures or other special features such as capitalized sales. Despite this special selection the correlation between accounting and economic rates of return was .79. If one could extend this work to all industries the correlation would presumably be significantly higher. There are, of course, some industries, such as pharmaceuticals, where the difference between accounting and economic profits are large, more in line with F&M's examples. But, as Stauffer emphasizes:

> "...there is little reason to expect that significant corrections would emerge for most firms, since the great majority of U.S. manufacturing industries seem to have relatively rapid inventory turnover, short gestation periods in plant construction, a comparatively low level of R&D or product development expenditure, and reasonably high ratios of working capital to fixed assets. ... Thus, extensive corrections to indicated rates of return should be the exception, rather than the rule." (page V-10).

F&M's examples, therefore, do not appear to represent the typical industry.

There is another atypical aspect to F&M's work. In all of their examples except Table 2, they employ a sum-of-years' digits depreciation schedule. The 1975 line of business survey of 472 large manufacturing companies indicates that approximately 80% of assets were depreciated with the straight-line procedure. Only about 9% use sum-of-years' digits. The use of straight-line depreciation in all of the examples would therefore be more appropriate if F&M wish to claim their examples are representative. The depreciation method selected is important, as can be seen in F&M's Table 2. The extent to which the accounting rate differs from the economic rate is smallest for the straight-line method. This is even more evident in Table 3 of Appendix A, which assumes an economic rate of return of 7.8 percent. For straight line depreciation the maximum difference between accounting rate of return on beginning-of-year assets and economic rate of return is 1.8, an error rate of less than 25 percent. The obvious explanation for straight-line depreciation's superiority is that for F&M's examples this depreciation method more closely approximates economic depreciation than the other methods considered.

There is some evidence that the superiority of straight-line depreciation is widely accepted. The Bureau of Economic Analysis of the Department of Commerce has, for several years, been concerned with accurately measuring depreciation in the national income and products accounts. Bureau economists have concluded that a straight-line depreciation method does, on average, more accurately characterizes economic depreciation than alternatives. For example, Young (1975) concludes:

> "The straight-line formula allocates depreciation equally to each year over the asset's service life. Selection of this formula is based on the view that the services provided each year are roughly equal and that no discounting should be used. It seems that for many, if not all, types of assets, the service provided remains fairly steady over much of the service life, and that substantial decline usually does not occur until near the end. Several empirical studies have indicated this pattern, particularly for long-lived assets such as buildings. ... Incorporation of a discount rate would tend to offset the difference noted between a depreciation formula that allows for a decline in service before the end of the service life and the straight-line formula." (p. 15 and 35).

Part of the problem F&M have is that they try to reach general conclusions about statistical relationships through examples. Such an attempt is fundamentally flawed, since the examples may only reflect extremes. The inaccuracy of this approach can be illustrated from other aspects of the profit measurement problem. Line of business (LB) profits may be distorted because of common cost allocations or nonmarket transfer prices. Benston (1979) and Breit and Elzinga (1980) illustrate through examples that in some cases these distortions can be quite large. And indeed, the LB data set does contain some profits which are significantly affected by these problems. But, as work by Long (1981), Ravenscraft (1981) and Long et. al.

(1983, p. 45-63) shows, large distortions are atypical. The correlation between LB profits as reported by the companies and LB profits based on a market-allocation procedure is approximately .89. Similarly, reported LB profits, for which 50% of the transfers are valued at nonmarket prices, and LB profits, where all transfers are valued at market prices, also have a correlation of approximately .89.

IV. The Usefulness of Accounting Profit Data in Structure-Performance Analysis

The required degree of accuracy of accounting profits is dependent on the context in which they are used. If a single accounting number is employed as evidence in an antitrust case, then certainly the accuracy of that number and not the typical accounting number needs to be ascertained. It is in this context that the F&M paper originated. However, they claim their analysis is relevant to more general situations, in particular the profit-concentration literature. There appears to be little justification for this extension of their analysis.

To connect their work with the profit-concentration literature, they must show how the accounting-economic-profit divergence leads to a positive bias in the concentration-accounting profits relationship. F&M never demonstrate that the use of accounting rates of return tends to over-estimate economic rates of return in concentrated industries relative to unconcentrated ones. Random noise in the accounting-economic profit relationship does not render profit-concentration regressions meaningless. In fact, the existence of a substantial amount of noise, caused by mismeasuring economic rates of return, would lead to the opposite conclusion. The statistical relationship between profits and concentration must be stronger than previous work indicates, because it prevails over a significant amount of noise.

We can present some indirect evidence that the accounting-economic profit divergence also does not significantly effect the qualitative conclusions of structure-profits regressions, even though it may introduce distortions for some individual profit numbers. As a first step, we calculated OLS regression statistics for a leading equation in Ravenscraft (1983), using profits/sales and profits/end-of-year assets as dependent variables. The results are given in columns (1) and (2) of Table 4, Appendix A. Two aspects of this exercise are worth noting. The first is that the profit/sales regression and the profit/assets regression yield similar structure-performance inferences, with respect to most of the key variables. This result is consistent with Bain's findings. The second result is that the strongest statistical results arise in the profit/sales regression, which lends support to the choice of profits/sales over profits/assets as the dependent variable in such regressions.

The corrected F&M examples point to the potential for a large difference between profits as a ratio to beginning-of-year and end-of-year assets, when there is a substantial accounting-economic profit divergence. Therefore, structure-profit regressions using profits/beginning-of-year assets and profits/end-of-year assets should yield different statistical inferences, if the accounting-economic profit divergence results in a significant bias. Implicit in their analysis is the expectation that mid-year assets should give intermediate results.

To test these hypotheses, we recalculated the profits/assets equation, but with mid-year assets and beginning-of-year assets as the denominator. The results are given in columns (3) and (4), respectively, of Table 4, Appendix A. Qualitative conclusions about individual independent variables for equations (2), (3) and (4) are almost identical. Therefore, there is little indication of a significant bias. We note that the R^2 with either mid-year or beginning-of-year assets in the denominator is substantially higher than R^2 with end-of-year assets, but that those two variants yield virtually indistinguishable results. Using profits/mid-year assets or profits/beginning-of-year assets reduces the standard errors, perhaps because, for 1975, they are better proxies of economic profits.

A third sensitivity test also indicates that the structure-profit results are generally not as biased as F&M suggest. If accounting depreciation corresponds to economic depreciation then accounting and economic profits are equal. Therefore, it is the divergence between accounting and economic depreciation that causes the accounting and economic profit divergence. If depreciation is a relatively unimportant part of profitability then the difference between accounting and economic profits should be small. To test for the impact of depreciation, equation (1) was re-estimated using profits before depreciation in the numerator. These results are shown in column (5) of Table 4, Appendix A. The statistical significance (using a 5% cutoff) of five of the twenty-three independent variables change as a result of the exclusion of depreciation from profits. These include minimum efficient scale (MES), supplier concentration (SCR), industry vertical integration (INDVI), industry advertising (INDADV), and industry R&D (INDRD). Therefore, mismeasurement of accounting profits does present some potential for distorting certain structure-profit results. However, F&M appear to be incorrect in their implication that the profit-concentration relationship is one of the results affected.

Other evidence which contradicts F&M's claim that concentration-accounting profits studies are biased can be found in the early work by Stigler (1964). His work reveals a positive relationship between accounting profits/assets and concentration, but he also discovered a positive relationship between the ratio of stock market value to book value of the firm and concentration. Furthermore, concentration was even more highly correlated with a firm's stock market value/ book value ratio than with accounting profit rates.

V. General Evidence of Accounting Profits Usefulness

Stigler's result that the stock market value/ book value ratio and accounting profit rates perform similarly when correlated with concentration suggests that accounting profits contain information which is used in the determination of market values. After an extensive review of empirical studies of this issue, Beaver (1981) concluded that the evidence shows that accounting earnings changes and stock market price changes are significantly positively related, and that prices behave as if accounting earnings data "... are a potentially important source of information, but only one of many sources." Presumably, the stock market reflects knowledge of economic profits, so accounting profits must do the same, at least to some degree, if investors consider them useful. If accounting profits yield absolutely no information about economic profits, as claimed by F&M, and the stock market employs such data in evaluating firms, then the implications of F&M's condemnation of accounting profits are much broader than they imply.

Actually, the implications of F&M's work, if correct, are enormous regardless of the stock market's efficiency. Accounting profit data are used to evaluate numerous economic issues. F&M have little justification for focusing solely on its use in evaluating monopoly. Many studies have used accounting profits to demonstrate the efficiency of large firms. Why not title the paper "On the Misuse of Accounting Rates of Return to Infer Efficiency?" The investment-profit literature is just as vast and important in terms of public policy as the profit-concentration literature, yet F&M did not even reference this literature, despite the fact that rate of return is the central concept in the investment literature. The growth and productivity literature implicitly assumes depreciation and assets are correctly measured. Even basic measurements in macroeconomics, such as GNP, are dependent on the accuracy accounting profit data.

The broad use of accounting profit data in the economy suggests that F&M's conclusions about the inaccuracy of the data must be wrong. The data are valuable by the most fundamental market test -- private firms spend vast resources collecting and analyzing them. A large number of commercial information services supply data on accounting profit rates and/or comparative analyses across firms or industries, and other firms pay for the use of the information. Dun and Bradstreet, Moodys, Value Line, Standard and Poors, COMPUSTAT, Data Resources, Inc., Chase Econometrics, Fortune, and Forbes are some of the more conspicuous firms which supply such services. Given the amount spent in the private sector on analyses of accounting profit data, a market failure of gigantic proportions is required to explain such an occurrence if the data are valueless.

VI. Conclusion

The flaws detailed above substantially limit the applicability of F&M's work. End of year asset figures are incorrectly calculated in all but the first table. The link between continuous and discrete time is incomplete and misleading. The data used in the examples are, with one exception, not derived from actual data. In fact, some data clearly do not reflect central tendencies. The one instance in which empirical data was employed, the wrong data was used. The theorems and proofs generated are not based on a profit maximizing model, and do not distinguish between marginal and average return.

Even if these problems are ignored, the implications of F&M's work are limited. The evidence they presented does not support the conclusion that accounting profit figures are meaningless. The paper simply implies that individual accounting profit numbers can under certain circumstances deviate significantly from economic profits. However, there is no evidence that large deviations exist on average.

On the other hand, evidence does exist indicating the value of accounting profit data. Work by Stauffer (1971) suggests that for most industries accounting profit data accurately approximates economic profits. Even in those industries displaying significant deviations between accounting and economic profits, the two measures are highly correlated. Other studies show a strong positive correlation between accounting profits and the stock market value of the firm. Therefore, either accounting profits have meaning or the stock market incorrectly values firms. Finally, the millions of dollars spent by private companies on generating and analyzing accounting profit data proves that it is indeed quite valuable.

F&M are equally wrong in their contention that the profit-concentration literature is a "misleading enterprise." They give no indication as to how accounting mismeasurement biases the profit-concentration relationship. The evidence presented in this comment, in fact, suggests the opposite; most of the structure-profit relationships are not significantly affected by accounting mismeasurement problems. Regressions using profit/assets with assets defined as beginning-of-year, mid-year or end-of-year yield similar results. F&M's examples indicated a large difference between the two end-point measures of profits, when the deviation between accounting and economic profits is large. Similar structure-performance results are also obtained using profit/sales as the dependent variable regardless of whether depreciation charges are included or excluded from profits. Depreciation mismeasurement, therefore, does not play the key role assigned to it by F&M. Lastly, Stigler (1964) found concentration to be positively related to both accounting profits and the stock market value of the firm, with the latter correlation being the strongest.

One final implication of F&M's work needs to be addressed. What if they were correct and accounting data are useless? Analyses of profit data or derivatives of profit data pervade every aspect of economics, micro and macro. How are public policy and corporate strategy decisions to be made? Economic theory can not be expected to give unambiguous answers to many of the critical issues. F&M do not address this question because they seem to believe their work has implications only for the measurement of monopoly power. But, this is clearly not the case. The only positive suggestion provided in the paper is one attributed to Zvi Griliches. Distributed lag analysis can yield estimates of the cash flow profile and therefore direct estimates of the economic rate of return.[8] If existing profit data are useless, then empirical work using distributed lag analysis should be given top priority. However, these studies require a time series of finely subdivided profit, assets, advertising and R&D data. Unfortunately, these data do not yet exist on a time series basis for a broad cross section of industries. Purely negative papers, such as Fisher and McGowan's, do not help attempts to collect the needed data.

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[8] The estimation of distributed lags is a difficult econometric task, as Griliches (1967) has pointed out. However, recent work by Hatanaka and Wallace (1980) does offer some hope. For an application of their procedure to the estimation of rates of return, see Ravenscraft and Scherer (1982).

Appendix A

Table 1 -- Asymptotic Accounting Rates of Return (%) on Three Versions of the Q-Profile

End-of-Year Assets Correction

Growth Rate	Six-year Life (No Delay): Straight Line	Six-year Life (No Delay): Sum-of-Years' Digits	Seven-year Life (One-Year Delay): Straight Line	Seven-year Life (One-Year Delay): Sum-of-Years' Digits	Eight-year Life (Two-Year Delay): Straight Line	Eight-year Life (Two-Year Delay): Sum-of-Years' Digits
A. Beginning-of-Year Assets						
0	15.2	18.1	18.1	22.0	21.0	25.9
5	15.2	17.0	17.0	19.4	18.9	21.7
10	15.1	15.9	16.0	17.1	16.9	18.1
15	15.0	15.0	15.0	15.0	15.0	15.0
20	14.8	14.1	14.0	13.1	13.3	12.3
25	14.7	13.3	13.1	11.4	11.7	9.9
30	14.5	12.6	12.2	9.9	10.3	7.8
B. End-Year Assets						
0	21.3	29.0	24.1	32.9	27.0	37.0
5	20.9	26.9	22.4	28.8	23.9	30.7
10	20.6	25.0	20.8	25.1	21.1	25.4
15	20.2	23.3	19.2	21.8	18.6	20.8
20	19.8	21.7	17.8	19.0	16.3	16.9
25	19.3	20.4	16.5	16.4	14.2	13.5
30	18.9	19.1	15.2	14.1	12.4	10.6

Table 2 -- Asymptotic Accounting Rates of Return (%) on Three Versions of the Q-Profile

End-of-Year Assets Correction, $r_{1b} = 0.15$, Growth Rate is Backward-looking

Growth Rate	Six-year Life (No Delay): Straight Line	Six-year Life (No Delay): Sum-of-Years' Digits	Seven-year Life (One-Year Delay): Straight Line	Seven-year Life (One-Year Delay): Sum-of-Years' Digits	Eight-year Life (Two-Year Delay): Straight Line	Eight-year Life (Two-Year Delay): Sum-of-Years' Digits
A. Beginning-of-Year Assets						
0	11.2	12.6	14.8	17.2	18.4	22.0
5	11.3	11.7	13.9	14.9	16.4	28.1
10	11.3	10.7	12.9	12.6	14.3	14.4
15	11.2	9.7	11.8	10.3	12.2	10.9
20	11.1	8.7	10.6	8.1	10.0	7.6
25	10.8	7.7	9.3	6.0	7.9	4.6
30	10.5	6.7	8.0	4.0	5.9	1.8
B. End-Year Assets						
0	15.7	20.2	19.7	25.9	23.7	31.4
5	15.6	18.4	18.2	22.1	20.8	25.5
10	15.3	16.7	16.6	18.5	17.9	20.0
15	15.0	15.0	15.0	15.0	15.0	15.0
20	14.6	13.3	13.3	11.7	12.2	10.4
25	14.1	11.7	11.6	8.5	9.6	6.2
30	13.6	10.1	9.8	5.6	7.0	2.5

Table 3 -- Asymptotic Accounting Rates of Return (%) on Three Versions of the Q-Profile

End-of-Year Assets Correction, $r_{0f} = 0.078$, Growth Rates Centered on 0.078

Growth Rate	Six-year Life (No Delay): Straight Line	Six-year Life (No Delay): Sum-of-Years' Digits	Seven-year Life (One-Year Delay): Straight Line	Seven-year Life (One-Year Delay): Sum-of-Years' Digits	Eight-year Life (Two-Year Delay): Straight Line	Eight-year Life (Two-Year Delay): Sum-of-Years' Digits
A. Beginning-of-Year Assets						
0	7.6	9.0	8.6	10.4	9.6	11.7
2.6	7.7	8.6	8.4	9.5	9.0	10.3
5.2	7.8	8.2	8.1	8.6	8.4	9.0
7.8	7.8	7.8	7.8	7.8	7.8	7.8
10.4	7.8	7.4	7.5	7.0	7.2	6.7
13.0	7.8	7.1	7.2	6.3	6.7	5.6
15.6	7.9	6.8	6.9	5.6	6.1	4.6
B. End-Year Assets						
0	10.6	14.3	11.5	15.6	12.3	16.7
2.6	10.7	13.6	11.1	14.1	11.5	14.7
5.2	10.7	12.9	10.6	12.8	10.6	12.7
7.8	10.7	12.3	10.2	11.5	9.8	11.0
10.4	10.6	11.6	9.7	10.3	9.0	9.3
13.0	10.6	11.1	9.3	9.2	8.3	7.8
15.6	10.5	10.6	8.8	8.1	7.6	6.4

Table 4. Alternative Measures of Profit Rates in a Structure-Profit Equation

	Op. Inc./ Sales (1)	Op. Inc. / Assets: End-of-year (2)	Op. Inc. / Assets: Mid-year (3)	Op. Inc. / Assets: Beg.-of-year (4)	Op. Inc. + Depr./ Sales (5)
INTERCEPT	-0.181	-0.203	-0.252	-0.285	-0.160
	4.13	2.78	3.38	3.55	3.73
CR4	-0.0247	0.00147	-0.0167	-0.0118	-0.0220
	1.47	0.05	0.59	0.38	1.34
MS	0.187	0.172	0.184	0.206	0.200
	4.91	2.73	2.86	2.97	5.39
MES	0.235	0.391	0.502	0.493	0.185
	2.09	2.09	2.63	2.40	1.68
BCR	0.0483	0.0352	0.0133	0.0153	0.0574
	2.78	1.22	0.45	0.48	3.38
BDSP	-0.00832	0.000857	0.00148	0.00149	-0.0108
	0.81	0.05	0.09	0.08	1.08
SCR	-0.0396	-0.0159	-0.0502	-0.0491	-0.0643
	1.23	0.30	0.92	0.84	2.05
SDSP	-0.0439	-0.0312	-0.0583	-0.0662	-0.0442
	2.13	0.91	1.67	1.76	2.19
LBVI	0.0133	-0.000855	0.00234	0.00437	0.0145
	1.47	0.06	0.15	0.26	1.64
LBDIV	0.0211	0.0535	0.0547	0.0669	0.0183
	1.75	2.67	2.67	3.05	1.55
GRO	0.0524	0.0921	0.104	0.108	0.0522
	7.07	7.49	8.23	8.00	7.22
IMP	-0.0666	-0.0272	-0.0375	-0.0413	-0.0534
	5.16	1.27	1.71	1.76	4.23
EXP	0.0404	0.0324	0.0727	0.101	0.0192
	0.85	0.41	0.90	1.17	0.41
DS	-0.0156	-0.0418	-0.0483	-0.0555	-0.0179
	2.29	3.68	4.16	4.45	2.67
LBADV	-0.0184	-0.167	-0.178	-0.184	-0.0755
	0.20	1.11	1.16	1.11	0.85

LBRD	-1.055	-0.488	-0.612	-0.828	-1.020
	12.11	3.37	4.14	5.21	12.00
LBASS	-0.0730	-0.106	-0.0970	-0.0955	-0.0410
	13.50	11.78	10.56	9.67	7.75
LBCU	0.170	0.196	0.276	0.320	0.163
	9.54	6.62	9.11	9.84	9.33
INDVI	-0.0300	-0.0567	-0.0664	-0.0688	-0.0231
	2.35	2.67	3.06	2.95	1.85
INDDIV	-0.0148	-0.0426	-0.0490	-0.0458	-0.0176
	0.72	1.24	1.40	1.22	0.88
INDADV	0.251	0.377	0.335	0.428	0.198
	2.01	1.82	1.58	1.88	1.63
INDRD	0.257	-0.399	-0.470	-0.264	0.417
	1.50	1.40	1.61	0.84	2.48
INDASS	0.0750	0.0206	0.0257	0.0208	0.0849
	5.31	0.88	1.07	0.81	6.15
INDCU	0.0361	0.0952	0.0776	0.0621	0.0278
	0.85	1.35	1.08	0.80	0.67
F RATIO	35.5	20.9	24.0	24.3	27.5
R-SQUARE	0.207	0.134	0.150	0.152	0.168

Number of observations: 3014.

The second line contains t-ratios.

TABLE 5

Abbreviated Name	Definition and Source	Mean	Std. Dev	Minimum[a]	Maximum[a]
BCR	Buyer concentration ratio: weighted average of the buyer's 4-firm concentration ratio (1972 CM & 1972 I-O Table, Martin(1981)).	.1983	.1534	.0020	.8410
BDSP	Buyer dispersion: weighted H index of buyer purchases (1972 I-O Table, Martin (1981)).	.2668	.2759	.0128	1.0
CR4	Adjusted Census 4-firm concentration ratio (Weiss (1981)).	.3870	.1705	.0790	.9230
DS	Distance shipped (in thousands of miles): radius within which 80% of shipments occurred (Weiss (1972)).	.8226	.3744	0.0	1.9360
EXP	Exports divided by value of shipments (1972 I-O Table).	.0604	.0637	0.0	.4925
GRO	Growth: 1976 divided by 1972 value of shipments (1976 ASM).	1.5713	.3536	.0047	3.3713
IMP	Imports divided by value of shipments (1972 I-O Table).	.0680	.1930	0.0	3.2510
INDADV	Industry advertising: weighted sum of LBADV for an industry (LB Data).	.0146	.0255	0.0	.2152
INDASS	Industry assets: weighted sum of LBASS for an industry (LB Data).	.6784	.1930	.1742	1.7887
INDCU	Industry capacity utilization: weighted sum of LBCU for an industry (LB Data).	.9369	.0664	.6181	1.0
INDDIV	Industry members' diversification: weighted sum of LBDIV for an industry (LB Data).	.7153	.1174	.1356	.9263
INDPCM	Industry price cost margin: industry Census value of shipments minus cost of material, payroll, advertising, R&D, and depreciation divided by value of shipments (CM & LB Data).	.2188	.0666	.0096	.4232

Name	Definition and Source	Mean	Std. Dev	Minimum[a]	Maximum[a]
MS	Market share: adjusted LB sales divided by an adjusted Census value of shipments (LB Data, 1975 ASM, 1972 I-O Table).	.0371	.0640	.0001	.5494
PRAT	Participation ratio: the summation of estimated market shares for industry members included in the LB sample (LB Data).	.4753	.2372	.0406	1.00
SCR	Supplier concentration ratio: weighted average of the suppliers' 4-firm concentration ratios (I-O Table, Martin (1981)).	.2456	.0739	.0340	.6100
SDSP	Supplier dispersion: weighted H index of inputs (1972 I-O Table, Martin (1981)).	.1221	.1165	.0273	.7773

[a]To avoid disclosing individual line of business data, the minimum and maximum of the LB variables are the average of the highest or lowest ten observations.

Source Codes:

ASM - Annual Survey of Manufactures, U.S. Department of Commerce, Bureau of the Census.

CM - Census of Manufactures, 1972, U.S. Department of Commerce, Bureau of the Census.

I-O Table - The Detailed Input-Output Structure of the U.S. Economy, 1972, U.S. Department of Commerce, Bureau of Economic Analysis.

LB Data - Line of Business Data, 1975, Federal Trade Commission, Bureau of Economics.

Name	Definition and Source	Mean	Std. Dev	Minimum[a]	Maximum[a]
INDRD	Industry R&D: weighted sum of LBRD for an industry (LB Data).	.0157	.0170	0.0	.1046
INDVI	Industry vertical integration: weighted sum of LBVI for an industry (LB Data).	.1344	.2019	0.0	.9974
LBADV	LB media advertising expenditures (traceable & nontraceable) divided by LB sales (LB Data).	.0138	.0314	0.0	.3175
LBADVMS	LBADV*MS (LB Data).	.0007	.0026	0.0	.0325
LBASS	LB assets (traceable & nontraceable gross plant, property and equipment plus inventories and other assets)*LBCU divided by LB sales (LB Data).	.6509	.4037	.0435	4.7367
LBASSMS	LBASS*MS (LB Data).	.0244	.0493	.0000	.5091
LBCR4MS	CR4*MS (CM & LB Data).	.0182	.0421	.0000	.4297
LBCU	LB capacity utilization: equal to 1975 divided by 1974 LB sales or one, whichever is smaller (LB Data).	.9166	.1310	.1875	1.0
LBDIV	Diversification: one minus a H index of a company's sales in each LB (LB Data).	.7431	.1904	0.0	.9403
LBMESMS	MES*MS (LB Data).	.0016	.0049	.0000	.0529
LBOPI	LB operating income (sales minus traceable & nontraceable operating and nonoperating costs) divided by sales (LB Data).	.0648	.1292	-1.1070	.5371
LBRD	LB private R&D expenditures divided by LB sales (LB Data).	.0145	.0286	0.0	.3171
LBRDMS	LBRD*MS (LB Data).	.0006	.0024	0.0	.0325
LBVI	LB vertical integration: dummy variable equal to one if vertically integrated and zero otherwise (LB Data).	.0756	.2645	0.0	1.0
MES	Minimum efficient scale: ratio of average plant size to industry size for the top 50% of the plant size distribution (1972 CM).	.0255	.0250	.0006	.2475

Appendix B

Part 1 -- Relations among economic rate of return, accounting rate of return, and growth rate in discrete time.

There are two theorems in F&M's appendix. The purpose of this part of Appendix B is to present general proofs of those two theorems for discrete time. As far as possible, we will follow the F&M sequence and use their notation, except that we use subscripts for the time index instead of parentheses. To facilitate comparisons, we will number our equations on the right, and where an equation is given that is an analogue of one of theirs, we will give that number on the left, but with a prime.

The first task is to define the economic rate of return. F&M did not give an explicit definition of the discrete time variable, but it is clear that they used:

$$\sum_{u=1}^{T} (1+r_{0f})^{-u} f_u = 1, \qquad \text{(B1)}$$

to define the rate of return, where f_u is the benefit accruing during the u-th time period, that is, between t=u and t=u+1. This definition assumes that investment takes place at the beginning of the first period (at t=0), and that benefits occur at the time period boundaries, starting with t=1. It is a "forward-looking" variant of the internal rate of return, in the sense that if $X_{t+1} = (1+r_{0f})\, X_t$, X_{t+1} is said to have the same value as X_t, where X is an arbitrary variable. Because of its beginning-of-year and forward-looking characteristics, we use the subscripts 0 and f to distinguish it.

This definition, which is commonly used, has a limitation. It ignores the possibility that investment may take place at some point in the first period other than its beginning. As shown below, in Part 2 of this appendix, analysis of investments which take place at an arbitrary point in the first period is needed. To fill that need, we use as a general definition of the economic rate of return the following:

$$\text{(A1')} \quad \sum_{u=1}^{T} (1-\beta r)^{u-1}[(1+r)-\beta r]^{-u} f_u = 1. \qquad \text{(B2)}$$

The variable β in this definition is a number between 0 and 1, inclusively, which notes the point in the first period at which the investment is made.

Since this is not the standard definition, except when $\beta=0$, some elaboration is needed. First, when $\beta=1$, the formula takes on a simple form:

$$\sum_{u=1}^{T} (1-r_{1b})^{u-1} f_u = 1. \qquad \text{(B3)}$$

We use the subscripts 1 and b for this rate, because it assumes that the investment takes place at t=1, and because it is "backward-looking", in the sense that if $X_{t-1} = (1-r_{1b})\,X_t$, X_{t-1} is said to have the same value as X_t. We also note that there is a simple conversion of this rate to the corresponding forward-looking rate: $r_{1f} = r_{1b} / (1 - r_{1b})$. Substitution into (B3) gives:

$$\sum_{u=1}^{T} (1-r_{1f})^{-u+1} f_u = 1, \qquad \text{(B4)}$$

which implies that

$$f_1 + \sum_{u=2}^{T} (1-r_{1f})^{-u+1} f_u = 1, \tag{B5}$$

so that

$$\sum_{u=1}^{T-1} (1-r_{1f})^{-u} f_{u+1} = 1-f_1. \tag{B6}$$

This last equation is useful in relating the beginning-of-year and end-of-year rates, since it shows that investment of one dollar at the end of the first year and receiving returns at the end of each year, including the first, is the same as investing one dollar less f_1 at the same point, and then receiving the rest of the returns at the end of years 2, 3, ...

To illustrate the impact that β has on the rate of return, we use the after-tax cash flow profile from F&M's Table 1. For an investment with a lifetime of 6 years, the cash flow (divided by the cost of the investment) is 0.257, 0.350, 0.371, 0.287, 0.154, and 0.064. For alternative values of β, we show the rates of return which satisfy equation (A1'):

β	0.0	0.25	0.5	0.75	1.0
r	15.0	14.5	14.0	13.5	13.0

For the definition of the book value of assets, we also need to generalize. For beginning-of-year assets, $V_\theta = \sum_{u=\theta}^{T} d_u$, and for end-of-year assets, $V_\theta = \sum_{u=\theta+1}^{T} d_u$, so we use $V_\theta = \sum_{u=\theta}^{T} d_u - \beta d_\theta$ for the general case, where d_u is depreciation, and $d_u = -V'_u = V_{u+1} - V_u$. Following F&M, the accounting rate of return is defined as

(A2') $b_\theta = (f_\theta - d_\theta) / V_\theta$. (B7)

We come, then, to the question of whether there are circumstances under which the accounting rate of return equals the economic rate of return.

THEOREM 1: $b_\theta = r$ if and only if

$$\text{(A3')} \quad V_\theta = (1-\beta r)^{-1} \sum_{u=\theta}^{T} (1-\beta r)^{(u-\theta)}[(1+r)-\beta r]^{-(u-\theta+1)} f_u \qquad \text{(B8)}$$

$$- (1-\beta r)^{-1} f_\theta ,$$

provided that β is not equal to 1. For that situation, book value of assets is zero in the last year, so there is clearly no depreciation schedule which can generate an accounting rate of return equal to the economic rate of return.

PROOF:

Let $\underline{f}$, $\underline{d}$ and $\underline{V}$ be vectors of cash flow, depreciation, and book value of assets, respectively. Also, let $x = (1-\beta r)^{-1}r$, E be an upper triangular matrix of one's, and F be an upper triangular matrix whose element is $(1+x)^{i-j-1}$, where i is the row number and j is the column number. Then $\underline{V} = (-\beta I + E)\underline{d}$ and $(\underline{f}-\underline{d}) = r\underline{V}$. Substitution and matrix inversion gives

$$\underline{d} = (1-\beta r)^{-1} (I - xF) \underline{f} \qquad \text{(B9)}$$

$$\underline{V} = (1-\beta r)^{-1} [-\beta I + (1-\beta r)^{-1}F] \underline{f}. \qquad \text{(B10)}$$

Equation (A3') is just an element of (B10). Q.E.D.

As in the continuous case considered by F&M, we assume a firm consists of a number of investments of different vintages, but all of the same type. Their finding that the accounting rate of return for the firm is a weighted average of the accounting rates of return for the individual investments also holds for the discrete case; we omit the proof to conserve space.

Turning to the impact of growth on the firm's accounting rate of return, we need to explicitly define the growth rate:

$$g = (X_{t+1} - X_t) / [(1-\beta) X_t + \beta X_{t+1}], \qquad (B11)$$

where X in an arbitrary variable. This definition is consistent with the definition of the economic rate of return and the measure of book value of assets, in that it incorporates the variable , which indicates the point in the period at which the base for the growth rate is determined. If $\beta = 0$, $g = g_f = (X_{t+1} - X_t) / X_t$. The subscript f distinguishes this rate as a "forward-looking" one, since it has the earlier period value as its base. At the other extreme, if $\beta = 1$, $g = g_b = (X_{t+1} - X_t) / X_{t+1}$. This is a "backward-looking" rate, hence the subscript b, since it has the later period value as its base. As with F&M, we assume g is constant.

To analyze the impact of growth, we need a base period, which we assume is the zero-th period. We let a be the accounting rate of return for the firm, and we denote by a_0 and a_1 the accounting rates of return with beginning-of-year and end-of-year assets as the denominator, respectively. We use π^*_t, δ_t, π_t, K^*_t, D_t and K_t, respectively, for gross profits, depreciation charges, net profits, gross assets, accumulated depreciation, and net assets for the firm at time t. The solutions for these six variables are given below, where $h = (1-\beta g)^{-1}[(1+g)-\beta g]$:

$$\text{(A15')} \quad \pi^*_t = h^t \sum_{u=1}^{T} h^{-u} f_u \qquad (B12)$$

$$\text{(A16')} \quad K^*_t = h^t \sum_{u=1}^{T} h^{-u} \qquad (B13)$$

$$= h^t (1-\beta g)^{-1} g [1 - h^{-T}]$$

(A17') $$\delta_t = h^t \sum_{u=1}^{T} h^{-u} d_u \qquad (B14)$$

(A18') $$D_t = h^t \{ (1-\beta g) g^{-1} [1 - h^{-T}] - (1-\beta g) g^{-1} [1 - (1-\beta g) \sum_{u=1}^{T} h^{-u} d_u] \} \qquad (B15)$$

$$= h^t (1-\beta g) g^{-1} [(1-\beta g)^{-1} h^{-t} \delta_t - h^{-T}]$$

$$= (1-\beta g) g^{-1} [(1-\beta g)^{-1} \delta_t - h^{t-T}]$$

$$\pi_t = h^t [\sum_{u=1}^{T} h^{-u} f_u - \sum_{u=1}^{T} h^{-u} d_u] \qquad (B16)$$

$$K_t = K^*_t - D_t \qquad (B17)$$

$$= h^t (1-\beta g) g^{-1} [1 - (1-\beta g)^{-1} \sum_{u=1}^{T} h^{-u} d_u]$$

Using these results, we can proceed to the second theorem.

THEOREM 2: a and r are always on the same side of g. That is,

$$a < g \iff r < g; \quad a = g \iff r = g; \quad a > g \iff r > g.$$

PROOF:

By definition, $a = \pi_t / K_t$. Substituting from (B16) and (B17) gives

(A21') $$a = g \left[\frac{(1-\beta g)^{-1} \sum_{u=1}^{T} h^{-u} f_u - (1-\beta g)^{-1} \sum_{u=1}^{T} h^{-u} d_u}{1 - (1-\beta g)^{-1} \sum_{u=1}^{T} h^{-u} d_u} \right]. \qquad (B18)$$

Substitution for h in the first term of the numerator in (B18) gives $(1-\beta g)^{u-1}[(1+g)-\beta g]^{-u}$ as the coefficient of f_u. Reference to the definition of r in equation (B2) shows that if $g = r$, this is just the coefficient in the definition of the economic rate of return. Consequently, the first term in the numerator equals one, so the second part of the theorem is proved.

If $g > r$, $(1-\beta g)^{u-1} <$ or $= (1-\beta r)^{u-1}$. In addition, $[(1+g)-\beta g]^{-u} <$ or $= [(1+r)-\beta r]^{-u}$. The strict inequality must hold for one of the two components; consequently, the coefficent in the first term of the numerator of (B18) is strictly less than the coefficient in (B2). It then follows that $a < g$, so the first part of the theorem holds. By a symmetric argument, the third part also holds. Q.E.D.

Two special cases are worth noting. When $\beta = 0$, r is r_{0f}, a is a_0, and g is g_f. This is the case illustrated in the F&M text. At the other extreme, when $\beta = 1$, r is r_{1b}, a is a_1, and g is g_b. This is the case illustrated in Panel B, Table 2, Appendix A.

Part 2 -- Discrete time approximation of continuous time: the superiority of mid-year asset measurement over beginning-of-year or end-of-year measurement.

In continuous time, investment is assumed to take place at $t=0$, and both gross returns and depreciation are continuous functions which begin at $t=0$ and continue for the lifetime of the project. As a result, cash flow also begins at $t=0$ and continues for the lifetime of the project. The integral of discounted cash flow (DCF) for the first period, i.e., from $t=0$ to $t=1$, measures the value of the cash flow stream for the first period, and a discrete estimate of that value would be the height of the DCF function at some point intermediate between $t=0$ and $t=1$. As a first approximation, it appears that the mid-point of the period should be useful for this purpose.

Using the midpoint, the height of the DCF curve is equal to $c(1/2)\ e^{-r/2}$ at the point $t=1/2$. If we substitute the discrete time discount factor of $(1+r)^{-t}$ for the continuous time discount cactor of e^{-rt} in this expression, we get $c(1/2)\ (1+r)^{-1/2}$ for the contribution to present value from the first period. If we now assume that the value of c is constant for $0 < c \leq 1$, we get as a measure for the first period $c(1)\ (1+r)^{-1/2}$. Extending this result for to all periods suggests $\sum_{t=1}^{T} c_t\ (1+r)^{-(t\ -\ 1/2)}$ as a formula which is appropriate for calculating the economic rate of return, in the sense that it is a reasonably accurate approximation of the continuous time formula for economic rate of return.

To illustrate this conclusion, we use the functions shown in Figure 1. The continuous cash flow function $c(t) = .371 - .046t$ is shown, as is the corresponding continuous DCF function $d(t) = (.371 - .046t)\ e^{-.15t}$. The economic rate of return is 15 percent. The integrals of d(t) for the six yearly periods are shown in Table 1, column (b). For each of three approximations, we use the mid-point values of the function c(t); they are given in column (d).

In column (e) we show the value of the function d(t) at the mid-points of the periods; as is obvious, the column (e) values are very close to the column (b) values. In column (f) we give the values of the discrete time variant of column (e), i.e., after substituting $(1+r)^{-(t\ -\ 1/2)}$ for $e^{-r(t\ -\ 1/2)}$. Once again, the values in column (f) are very close to the values in column (b). For comparison purposes, we show in column (g) the discrete time variant when the discount term is $(1+r)^{-t}$. The column (g) values are poorer approximations of the column (b) values.

The definition of the discrete time economic rate of return which F&M use is the one illustrated in column (g). As an approximation to the continuous time variant of the economic rate of return, it is deficient relative to the approximation illustrated in column (f). In fact, if their definition is used with the data in the illustration, the economic rate of return would be calculated as 12.8 pewrcent, not 15 percent, which is its true value.

Table 1. Alternative Discrete Approximations of the Continuous Present Value Function

Continuous Case

Cash Flow: $c(t) = .371 - .046\ t$

Discounted Cash Flow: $d(t) = (\ .371 - .046\ t\ )\ e^{-.15t}$

$$\int_0^6 d(t)\ dt = 1$$

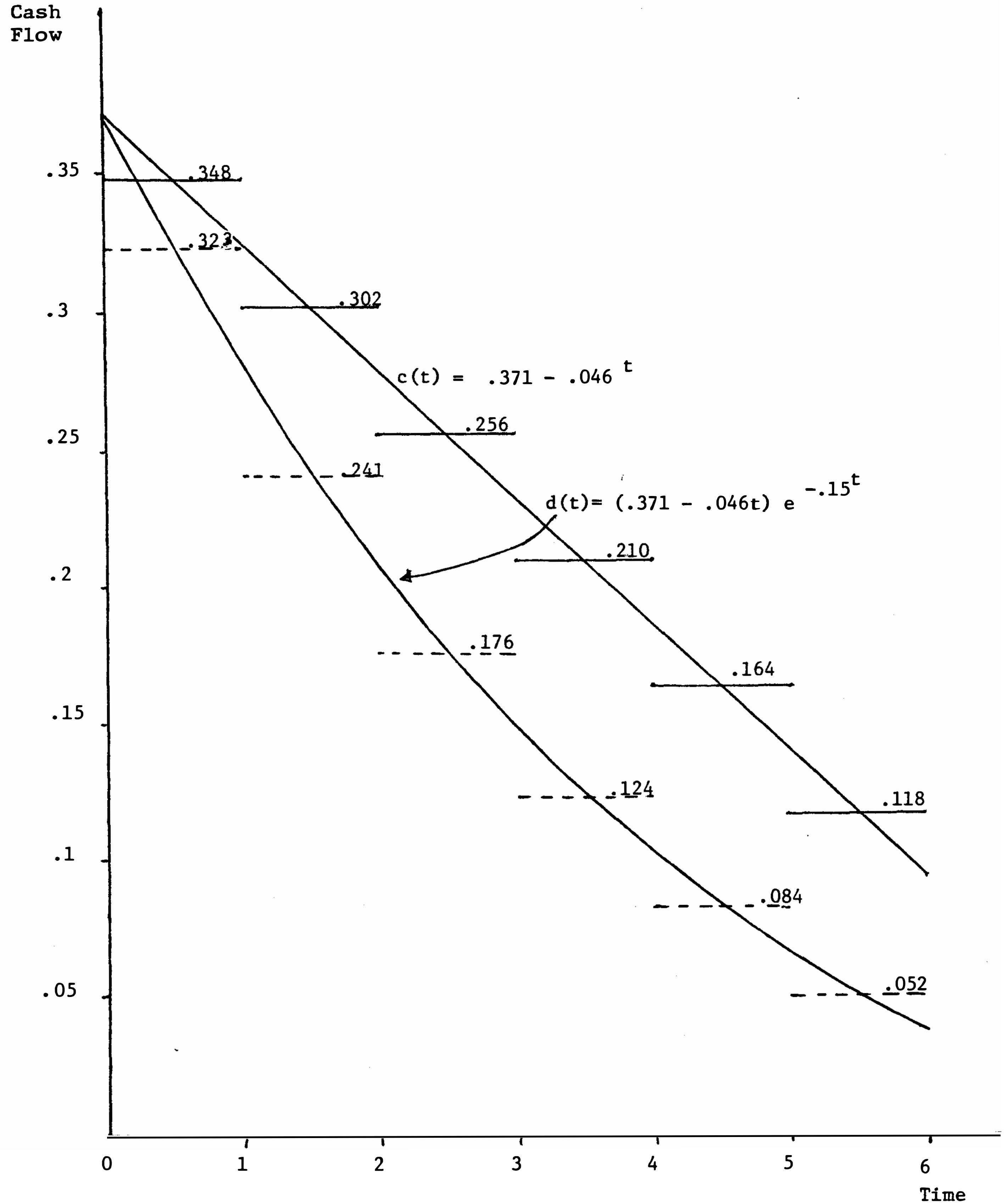
Discrete Case

Cash Flow: $\hat{c}_t = .394 - .046\ t$

Discounted Cash Flow: $\hat{d}_t = \sum_{t=1}^{6} (1.15)^{-(t-1/2)}(.394-.046t)$

Period	Integral	Midpoint	c(midpoint)	d(midpoint)	$\hat{d}$(midpoint)	$\hat{d}$(endpoint)
(a)	(b)	(c)	(d)	(e)	(f)	(g)
0-1	.324	0.5	.348	.323	.325	.303
1-2	.242	1.5	.302	.241	.243	.228
2-3	.177	2.5	.256	.176	.180	.168
3-4	.125	3.5	.210	.124	.129	.120
4-5	.084	4.5	.164	.084	.087	.082
5-6	.052	5.5	.118	.052	.054	.051

Figure 1



Cash Flow
.35
.3
.25
.2
.15
.1
.05
.348
.323
.302
.256
.241
.210
.176
.164
.124
.118
.084
.052
c(t) = .371 - .046 t
d(t)= (.371 - .046t) e -.15t
0
1
2
3
4
5
6
Time

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