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The evaluation of factors affecting machinery investment in the agricultural sector has long been debated by economists. Variation in investment exists both over time and across individual farmers. Cromarty; Fox; Griliches; Heady and Tweeten; Hrubovcak; LeBlanc and Hrubovcak; Penson et al.; and Rayner and Cowling have estimated investment relationships using aggregate time series data.[1] Major factors influencing investment were tractor and commodity prices, capacity depreciation, and tax law. However, the aggregate data used in these studies were historical averages, contained aggregation bias, and did not explain the investment behavior of farms with differing structural characteristics.

Important determinants of investment implied by financial theory are discounted expected net returns. Empirical applications of past investment studies have failed to include the three components of this theoretical construct. Only the studies by Griliches, Hrubovcak, and Penson et al. found investment levels related to changes in interest rates. Other studies have either found that interest rates effects were small or they had difficulty specifying the discount rate and the annual incremental returns attributed to the investment.

Past investment data only permitted historical specification of explanatory variables; they did not capture the expectations of farmers. Yet, farmers have substantial interest in and need for outlook information and decision aids when evaluating machinery investments. Thus, investment levels are influenced by expectations of future economic environments in addition to a firm's actual historical performance.

Finally, data availability often limits the specification of net returns. Strack and Girao, Tomek, and Mount estimated investment relationships with farm record data. Relationships for farmers with differing structural characteristics were derived. However, explanatory variables derived from record

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Cole R. Gustafson is assistant professor, Department of Agricultural Economics, North Dakota State University, Fargo. Peter J. Barry and Steven T. Sonka are professors, Department of Agricultural Economics, University of Illinois, Urbana-Champaign. The paper is based on a study cooperatively sponsored by the Economics Research Service of the United States Department of Agriculture and the University of Illinois.

data, aggregate data, and other forms of accounting data, frequently originate from cash transactions and fail to correspond to economically acceptable definitions which are useful for the explanation of investment behavior (Fisher and McGowan).

The objective of this study was to evaluate the important factors influencing the machinery investment decisions of Illinois cash grain farmers using an experimental method involving simulated investment situations. These farms have differing structural characteristics and face continual changes in their decision environment. Recent changes have occurred in (1) farm legislation, (2) regulation of financial institutions, (3) monetary policy, and (4) tax law. Selected farmers reviewed a computerized set of financial statements, simulating the performance of their farms. They were asked to make a sequence of investment decisions under differing policy scenarios. Variables characterizing the investment situations were statitistically related to the farmers' decisions. A secondary objective was to test the use of the experimental method in agricultural economic studies.

Theoretical Setting

When maximizing utility, the sole proprietor of a farm business is confronted with two decisions. The first choice concerns the individual's pattern of consumption over an expected time horizon. The other choice involves capital investment and withdrawals in the farm business. Capital withdrawals from the farm business which support consumption are limited by past investment.

If organized financial markets exist, Fisher's Separation Theorem states the optimal combination of investment and withdrawals from the production unit occurs at the point of tangency between the transformation curve of the firm and the capital market line.[2] The theorem limits the array of factors which must be evaluated in a study of farmer's investment behavior. Optimal investment requires no information on the proprietor's consumption preferences or utility function. The decision is based solely on the firm's technology and market rate of interest. Investments are undertaken as long as their rate of return is greater than the market interest rate.

Still, individual factors influencing a farmer's investment decision are numerous. The technology of a firm is a function of firm size, existing machinery complement, geographic location, enterprise combinations, and operator tenancy. The rate of

return to a machinery investment depends on commodity prices, yields, operating and ownership expenses, and public policies affecting the agricultural sector. An investment's rate of return to equity is determined by a firm's financial leverage and cost of debt.

Among these variables, the relative importance of structural characteristics and public policy to Illinois cash grain farmers making investment decisions was unknown. A priori, a farmer's tenure, financial leverage, and age of their machinery complement were hypothesized to be statistically associated with investment. The direction of the first relationship was ambiguous since renters may invest more often to obtain equipment that is more reliable, permitting timely field operations which satisfy land owners. However, rental arrangements are frequently renegotiated annually--creating greater uncertainty for tenant farmers. The relationship between leverage and investment was also ambiguous since high leverage could result from high investment financed with debt, or high leverage and the associated financial risk could inhibit additional investment. Finally, as the age of farmer's machinery complement increases, investment was expected to increase so capital stock levels and depreciation tax deductions could be maintained.

Changes in public policy may also influence farmers investment behavior. In the spring of 1986, three alternative proposals were considered most important to Illinois cash grain farmers. The first consisted of lower commodity price supports originating from the Administration's more market oriented farm legislation proposal. The second alternative reflected the Administration's proposed revision of the United States tax code. Under revised procedures, farmers would face lower marginal tax rates, a repeal of investment tax credit, and extended but inflation-indexed depreciation schedules. The third proposal was a state-sponsored interest rate buy-down program. The effect of the program was to reduce the interest rate on debt incurred to finance machinery investment by 30 percent. We hypothesized lower commodity prices and the repeal of investment tax credit would lower machinery investment if the first two proposals became law. The third proposal would have likely increased the net present value of a machinery purchase and increased investment.

An experimental approach was chosen to test the above hypotheses because characteristics of individual farms could be incorporated in the analysis, it permitted greater control over the various variables affecting machinery investment decisions and allowed the testing of investment responses to new public policies which previously had not existed. Inferences derived

from the analysis of historical investment data analyzed either econometrically or in the context of a math program are invalid if the farm decision environment changes significantly. Other problems associated with historical data were discussed in the introduction. Being farmers consider numerous economic and non-economic factors when making an investment decision, and do so over extended periods of time, administration of a survey instrument which controlled variables outside those of interest would be difficult. It is costly and difficult for the experimental approach to elicit investment decisions over time also. However, the passage of time could arise with simulation of investment situations.

Experimental Design and Participant Selection

Experimental methods have been used in a small but increasing number of agricultural economic studies. The elicitation of utility functions for identifying and measuring risk attitudes is a type of experimental approach. Participants may actually partake in the experiment's outcome (Binswanger). However, few real experiments are conducted because of limited resources and social concerns regarding preferential treatment of participants. A second type of experiment involves the analysis or management of case farm situations. Participants may be randomly distributed to cases or assigned to cases with characteristics similar to their own firm. However, without resources at risk, participant actions may differ in experimental and real world situations. Constructing cases that approximate a farmer's decision environment is difficult since farms are dynamic and face unique uncertainties. Experiments using case studies have elicited lenders' credit responses to various managerial actions and farm business characteristics (Barry, Baker, and Sanint; and Pflueger).

In this study the participant's own financial records were used to construct investment situations during the simulation process. The experiment was real in the sense the farmer's own data were used. However, the participant had no economic stake in the outcome. Hopefully, the participants interest in the experiment's outcome was heightened, prompting them to behave as if they actually faced the simulated investment situation.

Experimental design refers to methods of sampling which reduce variation and acquire information at minimum cost. It is based on the principle of making all behavioral comparisons among relatively homogenous groups of subjects or experimental units. The more homogenous the experimental units, the easier it is to detect differences in behavior. Many alternatives are available

including random, random block, and factorial designs (Snedecor and Cochran). A factorial design was chosen for this study because of the intensive one-on-one nature of the simulation process described below. Factorial designs are more efficient than random block designs since each observation supplies information about all factors included in the experiment.

Illinois is a diverse state agriculturally. Since cash grain production is an important component of agriculture in Illinois and the surrounding region, this type of farm was chosen for analysis. Farmers were chosen from the membership of the Illinois Farm Business Farm Management (FBFM) Association. The FBFM farm record data base is cooperatively sponsored by the University of Illinois Cooperative Extension Service and the Department of Agricultural Economics (Wilken). In 1983, 7,977 farmers from 10 regional associations cooperated.

To improve homogeneity and exclude northern crop and livestock farms and southern double crop farms, only members of FBFM associations in central Illinois were considered. Acreage of corn, soybeans, wheat, and set-aside had to account for 95 percent of crop acreage, and income from livestock production could not exceed 5 percent of total cash receipts.

Results of previous economies of size studies imply larger farms have significant investment advantages over smaller farms in Illinois, at least for expansion in the smallest regions of farm size (Batte and Sonka; Scott; and Van Arsdall and Elder). Since the relationship between farm size and investment has been already studied, farms of less than 300 acres were excluded. Also, farm records had to be classified as usable and farmers must have been members of FBFM from 1976 to 1983 so farmer's historic investment behavior could be compared with their decisions in the experiment. These restrictions narrowed the sample to 78 farms.

Farmers with differing land ownership, leverage, and age of machinery complement positions were selected from this sample and asked to participate in the experiment. A priori, these three structural variables were expected to have the highest statistical relationship with investment behavior. Given a factorial design, three structural variables, and the desire to compare the behavior of groups whose members are as homogenous as possible (i.e., compare investment of farms with high leverage, land ownership, and new machinery against farms with high leverage, land ownership and old machinery), eight distinct groups of farmers were identified reflecting the alternative combinations (2^3) of structural variables.[3] To establish boundaries defining each of the eight groups, the 78 farms remaining in the sample were sorted and crosstabulated.

To sort, continuous variables representing the three structural variables were derived from FBFM data. Since the FBFM data do not report any balance sheet liability measures, a leverage measure was based on the ratio of interest paid to gross income. Land ownership was defined as the ratio of an operator's real estate assets to the respective farm's total real estate assets (sum of operator and landlord shares). Rather than using acreage, this variable is based on value and reflects differences in soil productivity. Land, in addition to cropland, was included but considered insignificant. The machinery age variable was an average of machine ages in the complement weighted according to market values.

The 78 farms were sorted three times, once on each continuous variable. After each sort, boundaries for the high, middle, and low groups were established. The group boundaries could have been determined statistically using a mean value and standard deviation. However, outlying observations skewed the selection. Therefore, boundaries on each variable sorted the farms into three sets of equal size.

During the sorting procedure a positive correlation between ownership and leverage was discovered. The groups of low ownership and high leverage farms for each machinery age contained no entries. Thus, the farms were first sorted on ownership and then each ownership set was sorted independently on leverage and age. Enumeration of farms falling into each of the eight groups completed the cross tabulation. Results are shown in Table 1.

TABLE 1. RESULTS OF CROSS TABULATIONS

Group Definition			
Ownership	Leverage	Age	No. in Sample
---------- percent	----------	-- years --	
Low $\leq$ 3.4	Low $\leq$ 0.0	Low $\leq$ 7.2	3
Low $\leq$ 3.4	Low $\leq$ 0.0	High $\geq$ 10.3	3
Low $\leq$ 3.4	High $\geq$ 6.7	Low $\leq$ 7.2	2
Low $\leq$ 3.4	High $\geq$ 6.7	High $\geq$ 10.3	5
High $\geq$ 19.8	Low $\leq$ 7.6	Low $\leq$ 8.3	4
High $\geq$ 19.8	Low $\leq$ 7.6	High $\geq$ 10.3	3
High $\geq$ 19.8	High $\geq$ 21.3	Low $\leq$ 8.3	3
High $\geq$ 19.8	High $\geq$ 21.3	High $\geq$ 10.3	4

One farmer from each group was selected based on a FBFM field agent's evaluation of the farmer's eligibility and interest in participating, the geographical proximity of the farmers to each other and the university, and the response of farmers to an invitation. Both farmers identified in group 3 were ineligible since they had retired from farming. Boundaries of the group were relaxed but a replacement was not found. Since the statistical methods discussed below do not require the eighth member, a decision was made to proceed with seven farmers.

Farmers cooperating with FBFM do not constitute a random sample of Illinois farmers. Thus, inferences to the population of Illinois farmers cannot be made with any statistical confidence. However, Mueller (p. 292) compared a sample of FBFM a random sample of Illinois farmers and found few differences in management ability after farms were adjusted for differences in the quality of basic resources. Also, 1,070 Illinois farms from USDA's 1984 annual Farm Costs and Returns Survey (FCRS) were cross tabulated using the previously discussed method. No machinery age or regional classifications were possible. Still, boundary definitions for the ownership and leverage groups shown in Table 1 were similar to those defined with the FCRS random sample.

Since the financial records of each farm were entered into a simulation model, the FBFM data source has a number of advantages over a random sample of farmers. These include standardized accounting records and increased accuracy due to reviews of field and state agents. Historical records were also available.

Experimental Procedure

The experiment consisted of four steps (Figure 1). The first step occurred prior to the on-farm visit. The participant was asked to complete a data input form, questionnaire, and attitudinal survey. The input form obtained FBFM record data necessary for the simulation exercise. Additional information about the farm's machinery complement, business and financial organization, operator age, expectations on commodity prices, yields, and interest rates were elicited in the questionnaire. The attitudinal survey asked the farmer to rank the importance of various factors in his investment decision.

In step 2, data from the input form were entered into a simulation model. The selected model was the Farm Financial Simulation Model (Shnitkey, Barry, and Ellinger). The model is a multiyear spreadsheet of a farmer's financial performance that reports results in terms of a set of coordinated financial

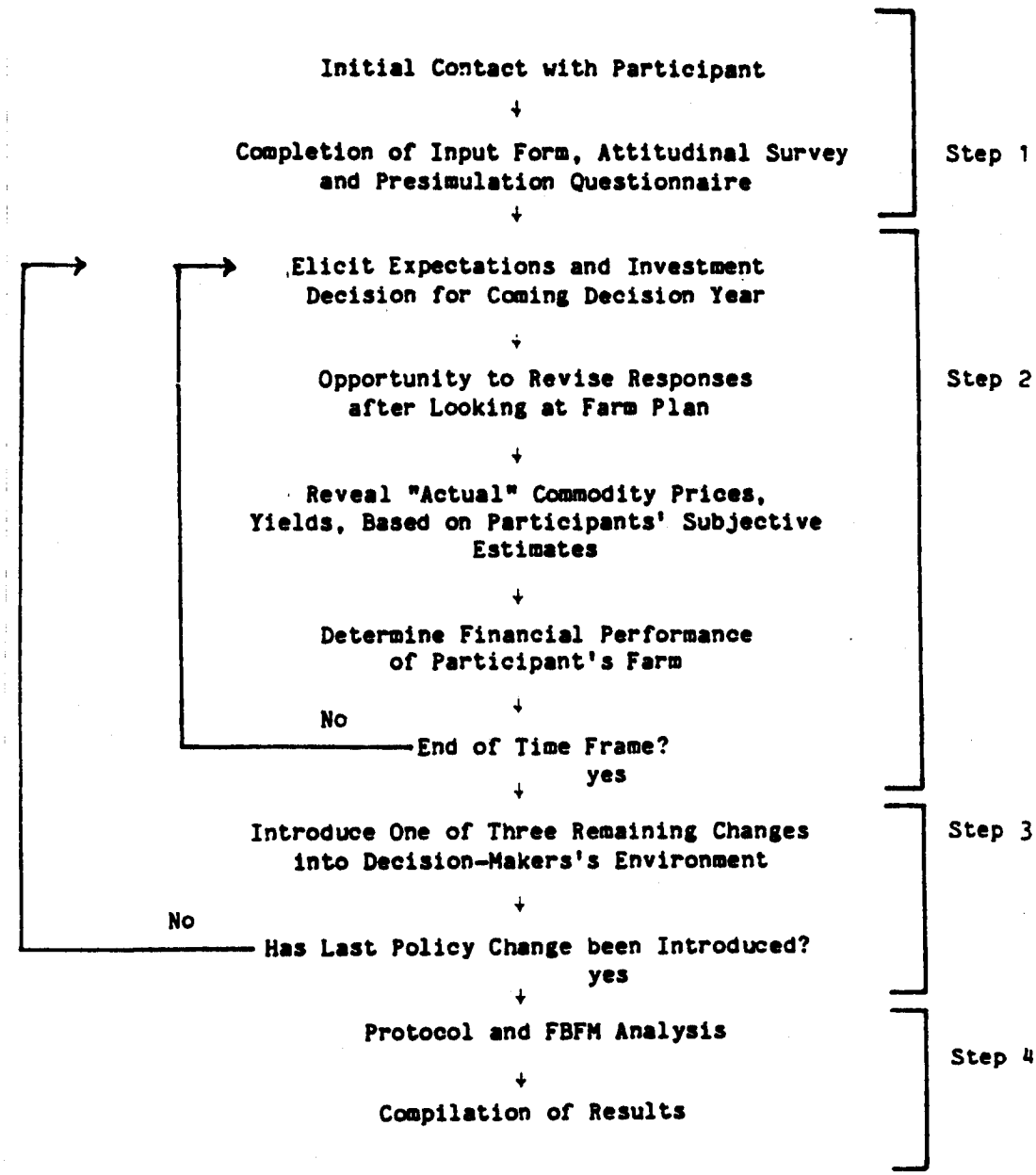

Figure 1. Simulation Procedure

statements. It was capable of simulating the financial performance of farms in alternative economic environments, providing instantaneous results and accommodating the farmers' individual situations. The model created the decision environment confronting the farmer and calculated the financial impact of any investment decision.

After the record data were entered, the following information was elicited from the farmers: (1) expectations of high, most likely, and low commodity prices and yields; (2) expected interest and inflation rates; and (3) their desired investment in farm machinery. These data were used to generate pro forma financial statements. After the farmer reviewed the plan, he could make any adjustments in acreage, investment, etc. that he felt was warranted. No limitations were placed on farm activities. For instance, land could have been rented or purchased to accommodate machinery investment.

Once the farmer was satisfied with the farm plan, "actual" commodity prices and yields were entered in place of the farmer's expectations. Commodity yields were randomly selected from a probability density function created by the farmer's subjective triangular estimates. Since farmers face income uncertainty in the real world, prices in the simulation exercise were chosen such that actual income deviated from expected income by a predetermined factor based on a historical coefficient of variation of gross income. As income prospects varied over the simulation period, farmers would also expect asset values to flucuate. Assuming a constant capitalization rate, asset values were adjusted with a one-year lag by the same income deviation. The same random number and income factor was used for all farmers in the same year of a given scenario. This process depicted the passage of time and created uncertainty in the farmer's decision environment. The farmer evaluated the actual yields and the firm's historical financial performance and then repeated the process by formulating another set of price and yield expectations, farm plan, and machinery investment decision. Four sequential decisions constituted a base scenario.

The third step introduced one of three alternative public policy scenarios into the farmer's decision environment. The simulation exercise was repeated with each alternative policy following a one week interval.

Post-simulation activities included validation of the simulation model and an econometric analysis of the data collected during the experiment. Results of a pretest, the attitudinal survey, observations on farmers' usage of financial statements during the experiment, and comparison of farmers' behavior during simultion with their historical investment actions ensured the experimental/simulation procedure modeled the farmers' operating environments.

In the pretest, eighteen students were presented with one of four case farm situations (Pflueger) and asked to participate in the base scenario and one of the three alternative scenarios. Further, students were sorted into three groups to determine if the level of income uncertainty, either large, moderate, or small, affected investment responses. Students had varied backgrounds, majors, and financial management skills. Overall, students reacted favorably to the exercise, describing it as "realistic," "very interesting and stimulating," and noting that "changes in market value of fixed assets enhanced realism." The level of income uncertainty introduced during the pretest was found to affect investment responses. Therefore, the level of uncertainty introduced to the farmers was necessary but restricted to historical levels.

Financial and investment data collected from the experiment were considered pooled since they consisted of both cross-sectional and time series dimensions. The time series dimension arose from the simulated sequence of annual decisions each farmer made while the two cross-sectional dimensions reflected the differing structural characteristics of farms in the sample and the alternative policy scenarios. Strack, and Girao, Tomek, and Mount assumed farmers altered their farm plans over the period of analysis and used a "random effects" model (Judge et al.). In this study, the policy cross sections are fixed by design. Similarly, farmers were not expected to quickly change the capital structure of their firms. Thus, the following "fixed effects" econometric model utilizing dummy variables was estimated:

$$y_{gst} = C_g + P_s + \sum_{k=0}^{K} B_k \, x_{kgst} + e_{gst}$$

$g = 1, 2 \ldots G$ refers to the different groups of farmers in the study according to structural characteristics

$s = 1, 2, \ldots S$ refers to the alternative policy scenarios

y_{gsc} is an investment observation for a farmer in the gth group in the tth period of time, and in the sth policy scenario

C_g, P_s variables represent the various cross-sectional dimensions

B_k, $k = 0, 1, \ldots K$ are the slope coefficients, again constant over time and cross-sectional units

x_{kgsc} is an observation on the k explanatory variable for a farmer in the investment situation described above

e_{gsc} is the random error for the gth and s^{th} cross sections in the tth time period and is assumed to have a zero mean, constant variance, and be independently distributed over time and cross-sectional units.

Variables C_g and P_s representing the structural characteristics and policy scenarios, respectively, were hypothesized to be significant. Financial variables x_{kgst} characterizing the investment situations are also expected to be significant.

Results

The average age of the seven participants was 53 years; only one was less than 50 years old. Two firms were organized as partnerships and both partners participated jointly in the experiment. All but one farm had annual off-farm incomes of $10,000 or less. All participated in the 1985 government price and income support program for farmers.

In the attitudinal survey, farmers ranked the importance of 13 factors influencing their machinery purchase decision on a scale of 1 to 4 (1 = very important, 2 = somewhat important, 3 = not very important, and 4 = not at all important). Availability of cash, high machinery prices, poor farm income prospects, and the condition of their present machinery complement were the four factors considered most important (Table 2). All farmers felt these factors were somewhat important. Least important factors were poor off-farm income prospects, advances in new machinery technology, the possibility of tax reform, and future land price declines.

Less uniformity existed in commodity price and interest rate expectations for 1986 to 1989 then in farmers' investment attitudes. Most farmers felt commodity prices would remain near the loan rate in 1986. By 1989, price expectations for corn ranged from $2.10 to $3.25 per bushel while expected soybean prices ranged from $5.00 to $7.00 per bushel. Interest rates on all types of loans were expected to decline through 1988 and then rise in 1989. Both operating and real estate interest rates were expected to range from 11 to 13 percent in 1986 and from 9 to 15 percent in 1989. One farmer expected machinery manufacturers to continue offering attractive financing plans. Therefore, interest rate expectations on machinery loans ranged from 5 to 17 percent.

TABLE 2. ATTITUDINAL SURVEY--RELATIVE IMPORTANCE OF SELECTED FACTORS IN INVESTMENT DECISIONS

Factor	Mean	Standard Deviation	Minimum	Maximum
High machinery prices	1.29	.49	1.00	2.00
Poor off-farm income prospect	3.14	1.07	1.00	4.00
Poor farm income prospect	1.29	.49	1.00	2.00
Possibility of major tax reform	2.71	.76	2.00	4.00
High interest rates	1.86	.90	1.00	3.00
Future government farm programs	2.00	.82	1.00	3.00
Condition of your present machinery	1.29	.49	1.00	2.00
Availability of cash	1.14	.38	1.00	2.00
Advances in new machine technology	2.86	.90	2.00	4.00
Greater indebtedness	1.57	.98	1.00	3.00
Availability of rented land	1.43	.53	1.00	2.00
Future land price declines	2.29	.95	1.00	3.00
Variability of farm income	1.71	.76	1.00	3.00

Investment responses of the seven farmers in the experiment's base scenario are shown in Table 3. The decision was solely up to the farmer. Both investment and disinvestment were allowed, however, none of the farmers chose to expand the size of their farm operation during the base scenario. Farmers made investments primarily to replace existing worn out machines.

During the experiment, farmers expressed a desire to maintain an even investment pace over time. The responses in Table 3, however, show considerable variation in machinery expenditures across the decision years. Perhaps the preference for uniform investment is a longer-run philosophy, or the discreetness of machinery purchases forces farmers to space investments more widely over time. Average investment over the four decision years varied across farmers from a low of $1,050 for farmer 8 to a high of $24,000 for farmer 2. Farmers 2 and 5 each invested $18,500 or more on average while the remaining farmers invested $5,750 or less annually.

TABLE 3. ANNUAL INVESTMENT RESPONSES--BASE SCENARIO

Farmer	Decision Year 1	2	3	4
	-------- net machinery purchased (dollars) ----------			
1	0	20,000	0	0
2	66,000	0	0	30,000
4	0	0	0	15,000
5	4,000	60,000	10,000	0
6	0	6,000	5,000	12,000
7	0	3,000	0	15,000
8	4,200	0	0	0

Annual average investment of the farmers in the market oriented and tax reform senarios varied only slightly from baseline levels (Table 4). In the interest buy-down scenario only farmer 2 decreased investment. Even though farmers did not change total investment across scenarios, the alternative public policies did cause farmers to change the timing of their investments-- particularly among the latter decision years. In the first year, farmers' behavior was constrained by historical investment decisions. For instance, farmer 2 sold his combine immediately after harvest in 1985 and had already negotiated the purchase of a replacement.

Differences in average income levels can be noted both across farms and policy scenarios (Table 4). The economic environments faced by farmers were quite different. During the base scenario, farmers 2 and 6 realized average annual net incomes in excess of $40,000, while the remaining farmers realized less than $25,000. Overall, incomes were lower in the market oriented and interest buy-down scenarios.

The debt-to-asset position is another variable distinguishing farmers' economic environments. Farmers with initially high leverage positions (4, 7, and 8) maintained high debt-to-asset ratios over the experiment. Likewise, with the exception of farmer 6 in the interest buy-down scenario, the remaining farmers maintained their relatively low initial leverage positions. Most farmers experienced higher debt-to-asset ratios in the market oriented scenario since they acquired more operating debt to meet cash flow requirements. Farmers were encouraged to acquire debt in the interest buy-down scenario which resulted in higher debt-to-asset ratios.

TABLE 4. AVERAGE ANNUAL NET FARM INCOMES, LEVERAGE, AND INVESTMENT RESPONSES OF FARMERS UNDER ALTERNTIVE POLICY SCENARIOS

	Base Scenario			Market Oriented Scenario			Tax Reform Scenario			Interest Buy-down Scenario		
Farmer	Investment Response	Net Farm Income	Debt-to-Asset Ratio	Investment Response	Net Farm Income	Debt-to-Asset Ratio	Investment Response	Net Farm Income	Debt-to-Asset Ratio	Investment Response	Net Farm Income	Debt-to-Asset Ratio
	($)	($)	(%)	($)	($)	(%)	($)	($)	(%)	($)	($)	(%)
1	5,000	19,818	.133	5,000	15,281	.138	5,000	15,931	.143	10,000	910	.156
2	24,000	45,586	.217	25,250	48,923	.222	20,250	52,436	.217	20,250	49,390	.223
4	3,750	13,630	.527	12,500	11,957	.541	10,000	2,660	.493	12,500	13,476	.544
5	18,500	-10,354	.061	8,500	-21,777	.065	18,500	-6,168	.061	18,500	-15,632	.093
6	5,750	40,775	.133	11,500	20,252	.154	6,000	43,638	.108	19,250	27,663	.427
7	4,500	24,533	.505	750	13,844	.520	4,500	16,229	.497	5,750	15,158	.505
8	1,050	17,182	.289	1,050	17,003	.314	1,050	19,923	.287	2,300	19,905	.700
Average over all farms	8,936	21,596	.266	9,221	15,069	.279	9,329	20,664	.258	12,650	15,839	.378

Table 5 presents selected statistics derived from farm record data which describe the historical operating environments of the farmers. Farmers' income and leverage positions in the experiment matched the past operating environment of their farm. Farmer 5, who had the lowest average historical income, also had the lowest income in the experiment. Average historical machinery investment responses from 1976 to 1985 varied among farmers. Farmers with the lowest historical investment did not necessarily invest the least in the experiment. For instance, farmers 2 and 4 invested the least historically. During the base scenario farmer 2 invested the most while farmer 4 invested the least. Farmers 1 and 6, with high historical investment levels, invested moderately during the experiments.

Net income and debt-to-asset measures are only two variables characterizing the decision environment confronting the farmers in the experiment. To determine these multivariate linkages, the remaining variables are identified and quantified as explanatory variables in a pooled cross-sectional time series investment equation.

Expected net returns, a discount rate, and the investment's initial cost are important explanatory variables of investment behavior according to financial theory. Normally these variables and those defining the alternative cross sections would be used to characterize the investment situation. However, the financial statements generated by the simulation model presented the farmers with many formulations of the same theoretical variable. Cash income, income from operations, and net income before and after gains represented different measures of net return. Further, financial variables can be derived from either historical or pro forma financial statements and as either absolute variables or ratios.

Regression methods require independence between explanatory variables. If correlations among the alternative empirical specifications of a theoretical variable exist, only one is permitted in each regression. Observations on individual farmer's usage of financial statements during the experiment lacked sufficient detail to make these variable selections but the observations can provide additional insight. Therefore, alternative measures of the variables themselves were used in the analysis to draw inferences about the types of data farmers apparently use as a base for making machinery investment decisions.[4] Following Judge et al., selection of a single set of regressors from the alternative combinations of explanatory variables was based primarily on Theil's corrected coefficient of multiple determination, $\bar{R}^2$. When the difference between $\bar{R}^2$ of two equations was small; economic theory, coefficient signs, the magnitude and significance of individual coefficients were all considered in addition to $\bar{R}^2$.

TABLE 5. SELECTED HISTORICAL FARM RECORD DATA FOR PARTICIPATING FARMERS--1976 TO 1983 AVERAGE*

Farm No.	Farm Size	Farm Size Growth	Average Machinery Investment	Gross Income	Net Farm Income	Interest Expense	Machinery Assets	Total Assets	Prices Received Corn	Prices Received Beans	Yield Corn	Yield Beans
	acres	(%)	dollars						$/bu.		bu/acre	
1	740	3	10,604	79,556	26,826	367	38,952	113,600	1.45	3.99	130	47
2	1,187	11	8,642	109,870	58,238	135	37,826	135,290	1.52	3.97	120	45
4	579	15	6,490	63,834	26,165	4,791	24,912	96,800	1.50	4.09	128	46
5	591	40	8,825	66,030	20,550	3,515	29,815	301,690	1.47	3.92	105	40
6	529	67	13,403	63,030	34,768	920	20,105	438,160	1.46	3.85	117	39
7	544	45	10,203	88,856	24,227	12,587	33,840	566,360	1.46	3.85	116	43
8	808	30	9,484	68,247	20,212	6,643	39,283	200,600	1.44	3.79	116	44

*All monetary values were deflated to 1977 dollars using the implicit price deflater for the gross national product.

The equation explaining most of the variation in the seven farmers' investment behavior during the experiment is shown in Table 6. It was the only equation with an $\overline{R}^2$ greater than .50. Initial regression results had Durbin-Watson values falling below upper test boundaries and mild negative first-order correlations among successive disturbances. Thus, investment decisions in two consecutive decision years were not independent. Problems of autocorrelation frequently emerge in time series data. Further, changes in economic variables may not instantaneously affect farmers' investment plans. As a result, the equations were reestimated using the Cochrane-Orcutt iterative method (Judge et al.).

TABLE 6. RESULTS OF ESTIMATED INVESTMENT EQUATION

Variable Name	Estimated Coefficient	Standard Error	Student T-Ratio 94 DF
High ownership	64,683.	15,172.	4.26
High leverage	-3,339.	2,378.	-1.40
High machinery age	12,968.	3,413.	3.80
Expected machinery price increase	637.	184.	3.46
Expected land price increase	-683.	245.	-2.78
Return on assets	-215,510.	36,745.	-5.87
Cost of debt	167,190.	25,645.	6.52
Current ratio	-0.002	0.006	-0.34
Intermediate ratio	0.014	0.004	3.69
Fixed ratio	0.049	0.011	4.38
Turnover ratio	212,170.	36,480.	5.82
Market ag 1	-630.	5,255.	-0.12
Market ag 2	-15,843.	5,027.	-3.15
Market ag 3	-4,070.	5,433.	-0.75
Market ag 4	-2,956.	5,135.	-0.58
Tax reform	55.	2,755.	0.02
Interest buy down	-788.	2,821.	-0.28
Constant	-90,979.	18,909.	-4.81

Note: Adjusted $\overline{R}^2$ = .60 Rho = -.21.

Structural Characteristics

HIGH OWNERSHIP, HIGH LEVERAGE, and HIGH MACHINERY AGE were dummy variables representing farmers with greater ownership in land assets, leverage, and age of machinery complements, respectively. A direct relationship was found between machinery expenditures and HIGH OWNERSHIP. As relative land ownership increased, farmers' investment in new machinery increased. During the experiment, tenant farmers expressed uncertainty regarding negotiation of future rental arrangements and were unwilling to invest in capital assets. Five of the farmers rented land on a share basis. Although share arrangements are renegotiated infrequently, one farmer felt his share of the expenses should be reduced since commodity price and land values have fallen but prices of purchased inputs which he must pay have remained high.

Machinery investment was also directly related to the age of a farmer's machinery complement. This relationship naturally follows from the need to maintain a machinery complement and even investment pace. Investment increased as average machinery complement age increased. Farmers having newer machinery complements initially as a result of either superior management or a desire to own new machinery, did not have higher investment levels than farmers with older machinery complements.

The negative coefficient of HIGH LEVERAGE implies an inverse relationship between investment and financial leverage. Farmers with relatively higher leverage positions invested less during the experiment, although the relationship was not statistically significant at the 95 percent confidence level. An ambiguous relationship was hypothesized since high leverage could result from high capital expenditures or high leverage could inhibit further investment. The latter depends on farmers' expectations. In favorable economic environments, farmers increase leverage and investment to maximize equity returns. In unfavorable economic periods, an inverse relationship between leverage and investment arises as highly levered farmers facing more financial risk strive to maintain cash balances. In the experiment, some farmers felt economic conditions would improve while others felt the opposite. This diversity in expectations may have masked the relationship between leverage and investment. Had expectations beyond 1989 been elicited, the relationship between investment patterns and leverage might have been revealed.

Expected increases in the value of farmers' machinery and land assets, as well as their firm's financial performance in the experiment influenced investment decisions. Expected percentage changes in machinery values (EXPECTED MACHINERY PRICE) did not reflect a constant rate of inflation but varied through time

(Figure 2). Yet, investment was directly related to these changes. As the value of a farmer's machinery complement increased, investment levels increased as well. The direction of this relationship was not hypothesized originally. An inverse relationship arose between expected percentage changes in land values (EXPECTED LAND PRICE) and investment. The direction of this relationship was also not hypothesized a priori.

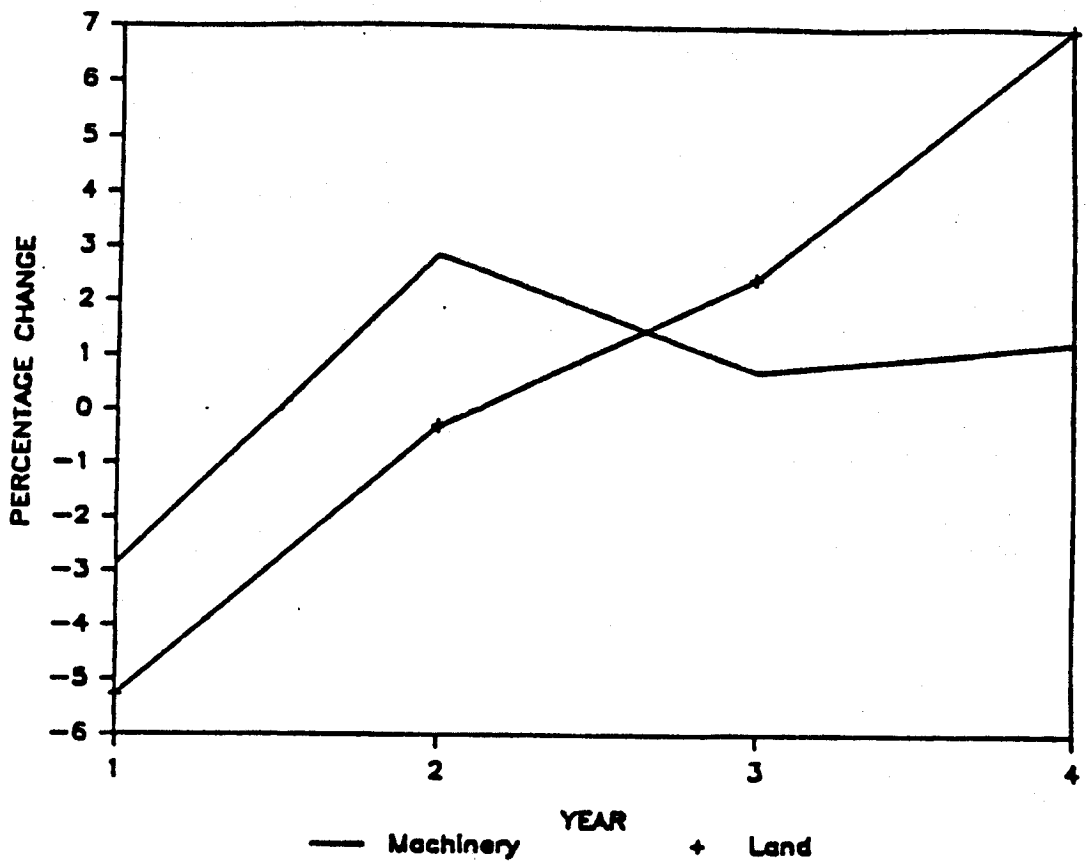

Figure 2. Expected Changes in Value--Land and Machinery

Farmers' investment decisions were associated with changes in their firm's financial position. Explanatory variables derived from historical financial statements were more significant than variables derived from pro forma statements. In the experiment, farmers usage of pro forma statements was minimal. Farmers appeared to base machinery investment decisions on the recent historical performance of their firm. One farmer remarked the only uncertainty faced was commodity yield and price variability. Pro forma statements were only implicitly evaluated by him since little change occurred in his firm's cost structure.

Financial ratios of profitability, liquidity, solvency, and efficiency were more closely associated with investment behavior than comparable variables constructed on an absolute basis. Except for the current ratio, all the financial ratios were statistically significant in explaining investment behavior. Individual current, intermediate, and fixed ratios had higher significance than a combined debt-to-asset ratio. The magnitude of the liquidity and solvency variables was small. However, they were directly associated with investment. Financial ratios that excluded contingent liabilities explained more of the farmers' investment behavior than ratios that included contingent liabilities. All of the farmers expected to remain in business and were uninterested in contingencies.

Return on assets and cost of debt variables were also more related to investment than returns to equity. Return on assets was inversely related to investment since asset levels increased when farmers invested. Repayment of outstanding loan balances and farmers' reluctance to acquire new debt over the simulation period reduced the impact of expected rises in interest rates during the final decision year. An efficiency variable defined as the ratio of gross revenue to total assets (TURNOVER RATIO) was statistically significant.

The constant term reflects the level of farmers' machinery investment unadjusted for other variables in the estimated equation. The size and significance of the coefficient supports farmers' desire to maintain uniform investment patterns. However, the significances of the remaining financial variables in the equation which characterized the investment situations suggests farmers do respond to changes in their operating environment.

Variables based on the coefficient of variation of corn and soybean prices and the level of income uncertainty introduced into the simulation were derived to assess the impact of risk on farmers' investment decisions. None of the risk variables were significant. As farmers became more optimistic over time, the upper area of the triangular price density function increased. The highest possible price for both commodities increased more than the most likely or lowest possible prices. Hence, the coefficient of variation increased and was possibly reflected in income trend variables. The purpose of introducing income uncertainty was to simulate farmers' actual economic environments. Evidently the induced uncertainty was not excessive as farmers' behavior was unaffected.

Alternative Public Policy Scenarios

The alternative public policy scenarios introduced into the farmers' decision environment consisted of more market oriented farm legislation, tax reform, and a state-sponsored interest rate buy-down program. Results show that the alternative policies influenced the timing of machinery purchases but did not substantially alter total machinery investment over the simulation period.

All farmers believed commodity prices would decline during the first two years of more market oriented farm legislation. Farmers' expectations for the latter two years were mixed, similar to the base scenario. Some believed prices would stagnate at lower levels while others felt reduced government stocks would create opportunities for higher prices. To test for differential investment patterns under this scenario, four dummy variables (MARKET AG 1-4) were created--one for each year of the new scenario.

The coefficient of MARKET AG 2 indicates each farmer on average reduced investment by $15,843 in the second year of a more market oriented agriculture. This reduction was statistically significant. Investment did not significantly change from baseline levels in other years. Farmers had already planned their capital expenditures for 1986 whereas variation in price expectations led to mixed investment responses in years three and four.

During the scenario of tax reform, farmers were expected to reduce investment in response to a repeal of investment tax credit (ITC). During the experiment, farmers stated ITC was a small factor in their investment decision for two reasons. First, spreading crop sales was a more effective means of income tax averaging than the purchase of machinery in high income years. Second, most machinery purchases were based on need and made prior to planting or harvest. Strack found similar purchase patterns in his investment study. When purchased prior to planting and harvest, income for the year and the usefulness of any ITC is uncertain. Indexation of depreciation deductions was attractive to farmers. With cyclical incomes, farmers believed the additional deductions could be utilized in at least one of the future years--hence farmers increased investment under tax reform.

The last scenario represented a state-sponsored interest rate buy-down program where the state assumed 30 percent of the interest when a new machine was financed. The coefficient of the dummy variable representing this scenario was insignificant and had a sign opposite that expected. Farmers purchasing machinery

during this scenario participated in the subsidy program and financed purchases with additional debt. Most purchases made during the base scenario were done with cash. Farmers' increased leverage positions in the scenario may have tempered additional purchases of machinery.

The magnitude and significance of the public policy coefficients was small relative to other explanatory variables. Farmers' behavior in the experiment was consistent with attitudes expressed in the survey. Public policy programs, particularly tax reform, were relatively unimportant in their machinery investment decision. Also, realized income in the alternative scenarios deviated only slightly from the base scenario. Perhaps more dramatic changes in total investment would occur if commodity prices were immediately set at market clearing levels or programs of tax reform and interest buy-down were more financially attractive.

Assessment of Experimental Methodology

The experimental methodology employed differed from methodologies used in past studies of farmers' investment behavior. The experimental method captured the individual characteristics of farmers participating in the study, allowed for greater control over the many factors affecting the investment decision, provided feedback to farmers about the results of their decision, provided insight into their decision making process, and permitted testing of investment responses to new public policies which previously had not existed.

Farmers appeared genuinely interested in the financial performance of their firms during the experiment. Many offered suggestions that improved the modeling of their firms. The realism of the exercise prompted consultation with their spouses or partners during difficult decision periods.

As with other approaches, the experimental method has weaknesses. During intervening periods between sessions, outside events influenced farmers' decision environments. Control of these factors would have been prohibitively costly. For example, Central Illinois gasoline prices fell 21 percent over the month of the experiment. Further, farmers heard numerous conflicting reports regarding details of the farm program before the passage of the Food Security Improvements Act of 1986. Finally, one farmer purchased a share in a grain truck at an auction sale. No mention of the intended purchase was made in earlier sessions.

Another weakness of the experiment concerned the range of particpants' financial analysis skills. Some were very capable financial analysts while others relied on FBFM field staff for financial analysis. Careful interpretation of the experimental data to these latter farmers was necessary to avoid bias.

The marginal cost of additional participants is usually small in experimental studies. However, the one-on-one nature of this study and the detailed record data necessary for simulation made it feasible for use with only a small number of farmers. Further refinements of the experimental method may reduce the approach's cost and permit the study of farmers' behavior in larger group settings.

Conclusions and Implications

The major conclusion to be drawn from this study is the need to consider the structural characteristics of individual farms when explaining the investment behavior of farmers. Explanatory variables representing the different land ownership, financial leverage, and age of machinery complement were highly associated with investment responses. Farmers with relatively higher land ownership, lower leverage, and older machinery complements had significantly higher machinery expenditure levels. Past studies of farmers' investment behavior have failed to account for these farm-level differences.

Farmers were found to have strong philosophical attitudes regarding the need to maintain an even pace of investment and a machinery complement in good repair. Efforts of public policymakers to alter farmers' investment behavior may be enhanced by a better understanding of the role played by these attitudes. The investment responses of farmers were relatively insensitive to the numeric specifications of the alternative public policy scenarios. Significant changes in total investment over the simulation period could not be statistically determined. However, farmers did alter the timing of their purchases from year to year in response to the policy changes and environmental conditions.

The results of this study have implications for future research studies. Most studies analyzing the impact of tax reforms on the agricultural sector have predicted significant change. Farmers in this study were insensitive to these changes. Perhaps revision affects nonfarm investors and/or specific farm enterprises, such as confinement livestock operations, more than operators of cash grain farms. Recommended optimal replacement strategies driven primarily by tax factors may have to be reevaluated also.

Farmers showed little interest in pro forma financial statements and the associated variables were not significantly related with their investment actions. A limitation faced by researchers using time series data has been the formulation of expected prices. The results of this study showed expected prices to be less important in a farmer's decision relative to other objectives, tasks, and environmental factors facing farmers. These additional factors may enrich behavioral models estimated with time series data.

Finally, the experimental approach can likely be applied to other types of investments besides machinery and other problems facing agriculture in general. The economic environment confronting farmers can be more fully evaluated in these settings. However, standard methods of statistical analysis are not easily applied. These methods are based on large sample properties where individual characteristics of firms are assumed to average out. New methods of analysis could increase the usability of experimental methods.

Footnotes

[1]References to the articles by Cromarty, Fox, Griliches, and Heady-Tweeten can be found in the review of machinery investment studies by Rayner and Cowling.

[2]See Fisher and Appendix A for a mathematical derivation.

[3]Frequently, members of a middle group (such as those with medium age machinery) would be selected to test for nonlinear relationships; the limited resources of this study did not permit this analysis.

[4]More than 300 equations were statistically estimated. All of the equations contained the dummy variables representing the structural characteristics of the farms and policy scenarios. The only difference among equations occurred in specification of finanacial variables. In addition to the various net income variables, alternative financial measures accounted for capital gains, contingent liabilities, whether the variable was derived from pro forma or historical financial statements, or calculated on a ratio or absolute basis. Each equation contained different combinations of these variables.

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APPENDIX A

The article referred to Fisher's Separation Theorem noting optimal investment and withdrawals from the farm business is a decision based solely on the firm's transformation curve and market rate of interest, requiring no information on the proprietor's utility function. The following is a mathematical derivation of this theorem.

The sole proprietor of a farm business is confronted with two decisions when maximizing utility.

$$\underset{c_1,\ \ldots,\ c_N;\ k_1,\ \ldots\ k_N}{\text{Max}}\ U(c_1,\ c_2,\ \ldots\ c_N) \tag{1}$$

The first choice concerns the individual's pattern of consumption $c_1, \ldots, c_N$ over an N-period horizon. In the last period:

$$c_N = f_N + y_N + k_N \tag{2}$$

The maximum amount of consumption equals the sum of the proceeds from financial securities carried over from previous periods f_N, income for the period y_N and capital withdrawals from the farm business k_N. Decomposing f_N,

$$f_N = (f_{N-1} + y_{N-1} + k_{N-1} - c_{N-1})(1 + i_{N-1,N}) \tag{3}$$

The one period yield (interest rate) on any financial resources lent (borrowed) from period N-1 to N is $i_{N-1,N}$--assuming perfect financial markets. After successive substitutions, the following capital market constraint arises:

$$c_1 + \frac{c_2}{1+i_{1,2}} + \frac{c_3}{(1+i_{1,2})(1+i_{2,3})} + \ldots + \frac{c_N}{\prod_{t=1}^{N-1} (1+i_{t,t+1})}$$

$$= f_1 + y_1 + \frac{y_2}{1+i_{1,2}} + \frac{y_3}{(1+i_{1,2})(1+i_{2,3})} + \ldots + \frac{y_N}{\prod_{t=1}^{N-1} (1+i_{t,t+1})}$$

$$+ k_1 + \frac{k_2}{1+i_{1,2}} + \frac{k_3}{(1+i_{1,2})(1+i_{2,3})} + \ldots + \frac{k_N}{\prod_{t=1}^{N-1} (1+i_{t,t+1})} \tag{4}$$

Thus, the present value of the sequence of consumptions equals the sum of present value of future earned incomes plus the present value of capital withdrawals and any initial endowment f_1.

The level of withdrawal opportunities, $k_1, \ldots, k_N$ from the production unit is limited by past investments. The timing of investments and withdrawals from the production unit is the proprietor's second decision which is represented by the implicit function:

$$T(k_1, k_2, \ldots, k_N) = 0 \tag{5}$$

A lagrangian expression with (1) and constraints (4) and (5) is formed to derive the optimal levels of consumption and investment:

$$U(c_1, c_2, \ldots, c_N) - \lambda_1 T(k_1, k_2, \ldots, k_N)$$

$$+ \lambda_2 - c_1 - \frac{c_2}{1+i_{1,2}} - \ldots - \frac{c_N}{\prod_{t=1}^{N-1} (1+i_{t,t+1})}$$

$$+ f_1 + y_1 + \frac{y_2}{1+i_{1,2}} + \ldots + \frac{y_N}{\prod_{t=1}^{N-1} (1+i_{t,t+1})}$$

$$+ k_1 + \frac{k_2}{1+i_{1,2}} + \ldots + \frac{k_N}{\prod_{t=1}^{N-1} (1+i_{t,t+1})} \quad . \tag{6}$$

Differentiating with respect to λ_1, λ_2, and each of the 2N decision variables, we have:

$$U'_1 - \lambda_2 = 0$$

$$U'_2 - \lambda_2 \frac{1}{1+i_{1,2}} = 0$$

.....

$$U'_t - \lambda_2 \frac{1}{\prod_{T=1}^{t-1} (1+i_{T,T+1})} = 0$$

.....

$$U'_N - \lambda_2 \frac{1}{\prod_{T=1}^{N-1} (1+i_{T,T+1})} = 0 \tag{7}$$

and

$$\lambda_2 - \lambda_1 T'_1 = 0$$

$$\lambda_2 \frac{1}{1+i_{1,2}} - \lambda_1 T'_2 = 0$$

.....

$$\lambda_2 \frac{1}{\prod_{T=1}^{t-1} (1+i_{T,T+1})} - \lambda_1 T'_t = 0$$

.....

$$\lambda_2 \frac{1}{\prod_{T=1}^{N-1} (1+i_{T,T+1})} - \lambda_1 T'_N = 0 \tag{8}$$

and the two first order conditions (4) and (5). Between any two periods,

$$-\frac{U'_t}{U'_{t+n}} = \prod_{T=t}^{-t+n-1} (1+ i_{T,T+1}) \tag{9}$$

which states the optimal allocation of consumption between two time periods, occurs at the point of tangency between an indifference curve and capital market opportunity line. Also,

$$-\frac{T'_t}{T'_{t+n}} = \prod_{T=t}^{-t+n-1} (1+ i_{T,T+1}) \tag{10}$$

which states the optimal combination of investment and withdrawals from the production unit occurs at the point of tangency between the transformation curve of the unit and the capital market line.

Therefore, where organized capital markets exist, an overall optimum of consumption, saving, borrowing, and investment by a sole proprietor is characterized by the simultaneous satisfaction of conditions (9) and (10). This fundamental double tangency solution is known as the Fisher Separation theorem. Condition (10) requires no information on the proprietor's consumption preferences or utility function. The decision is based solely on the firm's technology and market rate of interest. Investments are only undertaken as long as their rate of return is greater than the market interest rate.

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