10.

Farm Investment Behavior

A CHARACTERISTIC of economic growth is an increase in the proportion of capital used relative to labor. In agriculture, economic development has been accompanied by an absolute increase in capital and an absolute decrease in labor. The relative increase in price of labor, especially as influenced by nonfarm sectors and by economic growth, and the development of technologies increasing the marginal rate of substitution of capital items for labor have made this trend possible. However, even within the category of capital, with this resource coming to dominate the input structure of agriculture as illustrated in Chapter 2, substitutions also have taken place. One of the major substitutions has been capital produced in the nonfarm sector for that previously produced in the farm industry. This trend was illustrated in Chapter 2 by the large increase in all purchased inputs and the quite rapid decline in nonpurchased inputs.

This substitution, both within the capital category and between capital and labor, has brought about a large increase in the capital investment of agriculture. Not only has aggregate investment increased, but also the investment per farm has risen even faster as farms have decreased in numbers and increased in size. In physical volume the amount of durable assets (including real estate) in agriculture increased by 60 percent between 1920 and 1959. The rise was even greater — 200 percent — for operating inputs. These investments which substitute for labor increase capital stock greatly, just as they increase labor productivity. Labor productivity increased 280 percent over the period 1926-59 while labor and horse inputs dropped 43 and 85 percent respectively in the same period.

In this and following chapters we analyze investment in several categories of durable resources including (a) all motor vehicles, and individual analyses for autos, trucks and tractors, (b) machinery other than motor vehicles, (c) building improvements and (d) some aggregates of all productive assets. A later chapter relates to farm buildings and real estate. This chapter is designed to: (a) illustrate graphically some of the major input substitutions taking place, (b) examine a theoretic framework for analysis of the investment process and (c) present several statistical investment models used for later empirical analysis. Details of the logic are presented in this chapter since the general framework is employed in the estimates of several chapters to follow. For convenience our discussion of the theoretical framework is couched in terms of farm machinery investment. However, it also applies to the other investment categories analyzed subsequently.

MACHINERY PRICE AND QUANTITY TRENDS

To summarize further some substitutions occurring in agriculture and to suggest the role of prices in them, Figures 10.1 to 10.4 present important trends for farm machinery, other major farm inputs and farm outputs from 1910 to 1959. Previous quantitative or econometric studies, this study included, have not adequately isolated the influence of labor price and other input costs on capital investment and demand. The graphic analysis which follows is subject to the limitations of a two-dimensional analysis, but does provide some insight into price-quantity relationships not reflected by more sophisticated econometric approaches.

As the price of machinery falls relative to other prices, especially labor wages, machinery input is expected to increase in relative importance as it is substituted for other resources. Machinery inputs, Q'_M, in the figures are measured as the services required to maintain farm machinery and motor vehicles (40 percent of auto) for productive purposes. Q'_M includes depreciation, license fees, insurance and interest on inventory.

While the general trend in ratio of machinery prices to operating input prices has been upward, it has been relatively stable (Figure 10.1). This stability, as compared to prices of inputs from sectors outside agriculture relative to those from within agriculture, arises from the high correlation of labor prices among nonfarm sectors supplying operating inputs and machinery to farmers. As Figure 10.1 also indicates, the ratio of farm machinery inputs to operating inputs also

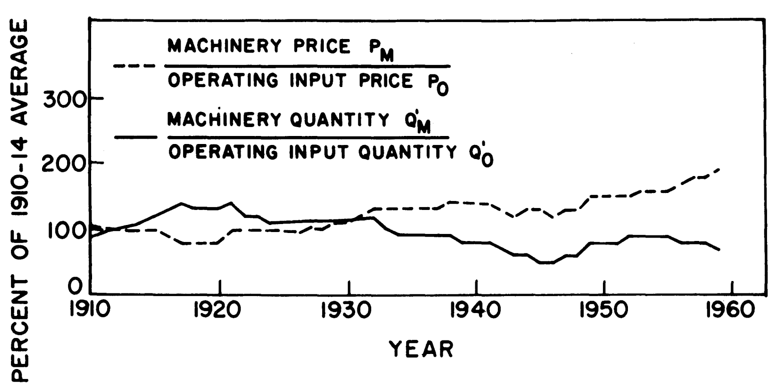

Figure 10.1. Ratios of farm machinery and operating input prices and quantities from 1910 to 1959 (1910-14=100).

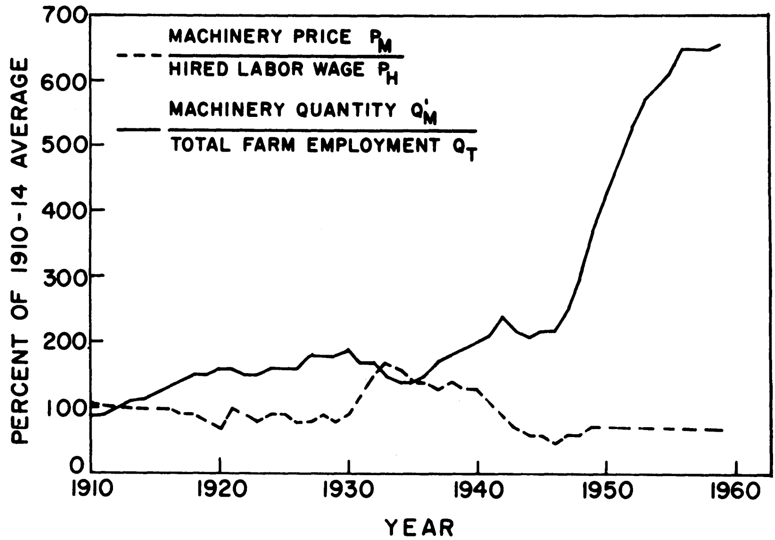

Figure 10.2. Ratios of farm machinery and labor prices and quantities from 1910 to 1959 (1910-14=100).

has been relatively stable over the period 1910-59. Stability in the quantity ratio is expected because machinery inputs such as tractors are technical complements with operating inputs such as fuel. Also, the same price and technical considerations of economic growth favoring improved machines also favored improved operating inputs over the period. In contrast to the degree of stability for machinery and operating inputs, Figure 10.2 indicates opposite trends in ratios of prices and quantities for machinery and all labor. Major substitutions have occurred particularly since 1946. The substitutions certainly cannot be explained by relative prices alone. The technological influences emphasized in Chapter 3 undoubtedly have been important. From 1910 to 1930, relative prices remained highly constant but machinery inputs increased relative to labor. New tractors, combines, etc., and improvement of existing models, increased the marginal productivity of machines relative to labor. Although price ratios remained almost unchanged from 1946 to 1959, the ratio of machinery to labor inputs grew rapidly. For the latter period, the relative decline in machinery price and increase in farmer capital position from 1940 to 1946 created a latent demand which could not be filled until the postwar period. Depreciation also depleted machinery stock in the war years, and machinery could not be replaced until the postwar era. Undoubtedly, improvements in existing machinery, introduction of new models and other nonprice influences also have encouraged substitution of machinery for labor inputs during the postwar period.

Figure 10.3 indicates the indices of the ratios: Q'_M to real estate inputs, Q_{RE}, and P_M relative to land price, P_{RE}. Despite the tendency

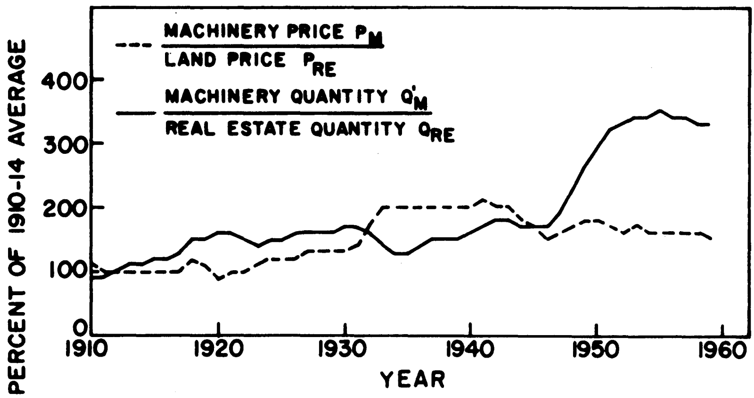

Figure 10.3. Ratios of farm machinery and real estate prices and quantities from 1910 to 1959 (1910-14=100).

for machinery prices to rise relative to land prices, the ratio Q'_M/Q_{RE} increased from 1910 to 1940. After 1940, machinery prices declined relative to land prices, and the relative importance of machinery inputs increased sharply. In the period 1955-59, however, the input ratio stabilized. The lack of correspondence between price and quantity ratio may arise because land price is not directly a decision variable in machinery purchases. Cash expenses such as hired labor and operating inputs, and the expected returns from sales of farm output, are examples of decision variables that may be of greater direct importance. However, since the marginal value productivity of land is affected by the magnitude of machinery inputs for the individual farmer, the price of land does have some importance in determining whether acreage can be profitably purchased or rented to complement added machine investment.

The two graphs in Figure 10.4 express: the ratio of P_M to prices received by farmers for crops and livestock, P_R, and the ratio of Q'_M

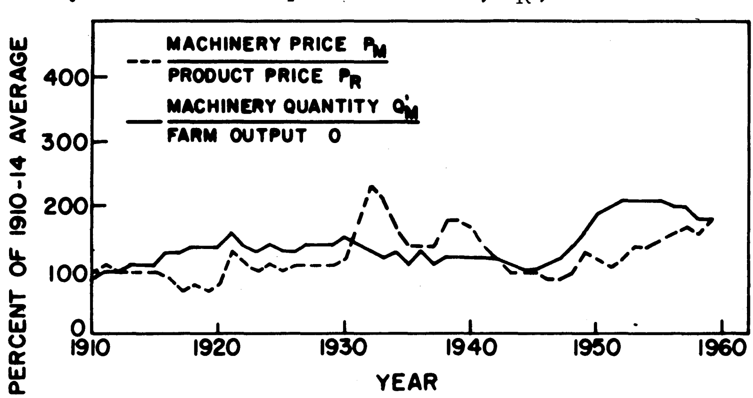

Figure 10.4. Ratios of farm machinery and farm output prices and quantities from 1910 to 1959 (1910-14=100).

to agricultural output O from 1910 to 1959. The quantity ratio was quite stable until 1940. During the decade of the 1940's, inputs of machinery declined in relative importance although prices were favorable because of conditions mentioned previously. In the late 1940's as machinery became available, the input began to substitute for other inputs in the production process. In the period when the backlog of demand was being filled, the quantity ratios ran counter to what might be expected on the basis of price ratios. After 1952, however, price-quantity interrelationships followed a pattern expected from theory.

PREVIOUS FARM INVESTMENT STUDIES

Previous econometric studies of demand for durable goods in agriculture, though few, provide useful insights into forces influencing the investment process. A study by Kendrick and Jones published in 1953 specified the outlay for farm plant and equipment (machinery and building improvement) as a simple function of net farm income.[1] Their least-squares analyses for the period 1910-41 indicated a significant relationship between income and investment. They estimated the income elasticity of demand for plant and equipment to be 1.08. Their data also suggested farm capital outlay was a relatively constant proportion — 20 percent — of net cash income. Griliches specified two principle demand functions for farm tractors: (a) the stock of tractors as a function of the past price of tractors relative to prices received by farmers for crops, the rate of interest and lagged stock and (b) the annual investment in tractors as a function of current price, the rate of interest and beginning year stock.[2] His estimates of price elasticities of the tractor stocks was -.25 for the short run and -1.50 for the long run. The adjustment coefficient was .17, indicating the long run is "far away." Elasticity with respect to the interest rate was approximately -1.0 in the short run and from -4.5 to -10.3 in the long run, quantities considerably higher than for the price elasticity. Specification of the price of labor, the price of motor supplies, a time trend, a capital gains variable, the stock of horses and mules on farms and alternative measures of the stock of tractors on farms did not improve the results.

Cromarty specified the demand quantity of farm machinery (value of manufacturers' sales of machinery deflated by the wholesale price index of machinery) as a function of: (a) machinery price, (b) the index of prices received by farmers for crops and livestock, (c) the index of prices paid by farmers for items used in production, (d) the value of farm machinery at the beginning of the year, (e) asset or equity position of farmers, (f) realized net farm income in the previous year,

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[1]Kendrick, John W., and Jones, Carl E. Farm capital outlays and stock. In Survey of Current Business. 33, No. 8:16-23. U.S. Dept. of Commerce. Washington. 1953.

[2]Griliches, Zvi. The demand for a durable input: Farm tractors in the United States, 1921-57. In Harberger, Arnold C. (ed.). The Demand for Durable Goods. pp. 181-207. The University of Chicago Press. Chicago. 1960.

(g) cropland acres per farm and (h) an index of labor costs.[3] A least-squares demand equation fitted to annual data from 1923 to 1954 explained 95 percent (adjusted R^2) of the variation about the mean of the dependent variable. Only variables (c), (e) and (h) were significant in the equation. The sign of the labor cost variable (h) was negative and does not support the hypothesis that machinery is substituted for labor as farm wages rise. In an alternative specification, he considered the machinery market as an interdependent system. The (a) deflated value of shipments of farm machinery, (b) retail price index of farm machinery and (c) value of machinery produced were determined interdependently in a system of three equations. The two predetermined variables that most significantly explained the three endogenous variables were (a) the wholesale price index of farm machinery and (b) industrial wage rates. Predetermined variables such as the parity ratio, beginning year assets, a quantified measure of farm price programs, changes in manufacturers' inventories, steel price and a measure of plant capacity had little influence on the endogenous variables — using the ratio of the coefficient to the standard error as the criterion.

SPECIFICATION OF THE INVESTMENT FUNCTION

Complex investment functions, providing for the macro-economic influences of multipliers and accelerators to explain cyclical fluctuations in investment, have been formulated by Samuelson, Hicks and others.[4] Refined models allowing for the macro influence of aggregate demand seem inappropriate for agriculture since: (a) agricultural investment is a sufficiently small portion of total investment and the macro effects may be ignored as a reasonable approximation and (b) it is necessary to construct less refined models compatible with statistical procedures and data limitations. The procedure in this study is to develop simple models consistent with the desired information of parameters in the investment process.

Durable asset theoretically should be purchased if the present value of discounted future earnings exceeds the cost of the asset. If uncertainty were absent, the rate of discount might be the bank rate of interest. But in agriculture a liberal discount for risk and uncertainty and capital limitations must be made. Future earnings are determined by the sales price of the product and the flow of services from the durable stock in the production function. Because the flow of services from a durable good tends to be proportional to stock, the annual investment essentially is derived from the desire by farmers for a given level of stock. For a durable input, the flow of services from stock rather than annual purchases is the relevant input in the production

[3]Cromarty, William A. The demand for farm machinery and tractors. Michigan Agr. Exp. Sta. Bul. 275. East Lansing. 1959.

[4]Cf. Allen, R. G. D. Mathematical Economics. Macmillan and Company. London. 1959. Chaps. 7 and 8.

function. It does not necessarily follow that the stock of assets rather than annual investment should be the dependent variable in the investment function. Although the objective may be an optimum inventory, the variable manipulated by farmers to achieve the proper level of stock is annual purchases (gross investment). In this study, annual investment, rather than stock, is chosen as the dependent variable. The former is a more volatile quantity and sensitive measure of investment behavior. Furthermore, by proper structuring of the investment equations, it is possible to infer results about stock levels from knowledge of annual investment. In the following pages a number of other variables are specified as relevant in the investment function.

Under certain rigid assumptions of classical economics, the volume of investment is determined by the cost of capital and the market rate of interest.[5] Growing awareness of the role of expectation in business cycles has caused more attention to be focused on investment behavior in recent years. The trend has been to relax the somewhat unrealistic classical assumptions resting so heavily on the rate of interest and to allow assumptions more nearly approaching real world conditions. Interest rates have been given a less prominent role in investment theory, and greater emphasis has been given to the nature of expectations. Profit maximization is less often assumed to be the sole motivator in the decision process, allowances being made for utility maximization, the desire for security (e.g., game theory minimax criterion), convenience, stability, etc.[6]

Lagged Stocks

The demand for gross annual investment normally is derived from two sources: (a) desire to increase stock to levels suggested by new values of decision variables and (b) need to replenish existing stock because of depreciation. The level of past stock exerts an opposite influence on these two sources of demand. The greater the level of beginning year stock, the greater the depreciation and demand for replacement stocks. But *ceteris paribus*, greater stock levels decrease the marginal product of investment goods and reduce the demand from the first source above. If we consider a declining balance depreciation method (depreciation a linear proportion of stock) to be realistic, beginning year stocks can be included in the linear investment function to represent the second source, the coefficient of lagged stock being the rate of depreciation. In some instances the rate of depreciation changes or the same level of stock at two points in time does not indicate comparable replacement demands because the total stock is newer at one point in time. Refinements such as these can be introduced into

[5]For further discussion, see Meyer, John R., and Kuh, Edwin. The Investment Decision. Harvard University Press. Cambridge, Mass. 1957.

[6]A brief discussion of several decision criteria is given in Walker, Odell, Heady, Earl O., Tweeten, Luther G., and Pesek, John T. Iowa Agr. Exp. Sta. Res. Bul. 488. Ames. 1960.

the demand function if necessary. The greatest challenge, however, is to select variables to express the first source of investment, the desire to increase or decrease stock levels. Several variables can be suggested for this purpose and are discussed below.

Net Farm Income

The variable most often suggested in empirical analysis of investment in nonfarm industries as the source of investment is net income or corporate profits. Studies by Meyer and Kuh,[7] Tinbergen[8] and several other studies cited by Kuh[9] show profit to be an important variable determining the actual rate of investment. Grunfeld states, however, that while profit may be a useful indicator of investment behavior, better indicators might be found.[10] He finds that the market value of the firm predicts investment better than profit. The studies of investment in agriculture by Cromarty[11] and Griliches[12] indicated no significant importance of net income in explaining demand for farm durables. But the study by Kendrick and Jones does indicate that net farm income is useful in explaining aggregate investment behavior.[13]

The argument for inclusion of net income in the investment function is strong. Net farm income (gross receipts less production expenses), Y_F, is an important expectation variable for two reasons. First, it is an indication of the returns from the durable resource. After subtracting production costs from gross returns, the remainder may be interpreted as the return to family labor and durable resources. Farmers subjectively and directly have imputed little return to their own labor. Hence, a tendency may exist to attribute a major part of the return to fixed capital. Theoretically, the decision to purchase a durable resource is made if the present value of discounted future earnings from the asset is greater than the purchase price. Because expected future earnings from durable resources probably tend to be based on past earnings, lagged values of Y_F in the demand function may be important.

A second reason exists for including Y_F in the investment function. The variable is an important indication of the future financial capabilities and ability to pay for the asset. Investment in a durable asset such as machinery entails considerable financial encumbrance in many

[7]Meyer and Kuh, op. cit.; and Meyer, John R., and Kuh, Edwin. Acceleration and related theories of investment: An empirical inquiry. The Review of Economics and Statistics. 37:217-30. 1955.

[8]Tinbergen, J. Statistical evidence on the acceleration principle. Economica. 5:164-76. 1938.

[9]Kuh, Edwin. The validity of cross-sectionally estimated behavior equations in time series applications. Econometrica. 27:197-214. 1959.

[10]Grunfeld, Yehuda. The determinants of corporate investment. In Harberger, Arnold C. (ed.) The Demand for Durable Goods. pp. 211-66. The University of Chicago Press. Chicago. 1960.

[11]Cromarty, op. cit.

[12]Griliches, op. cit.

[13]Kendrick and Jones, op. cit.

instances. Although the current price of machinery may be low relative to prices received, a farmer may hesitate to invest unless he feels assured of future earning potential, and the degree of assurance often depends on past income, and equity which he has built up out of it. Financial institutions employ similar decision variables to determine the feasibility of a loan. External credit availability is often determined to a greater extent by the ability to repay the loan than by the profitability of the specific investment. Equity, as a facet of past net income, again is important in this respect. Even though the marginal efficiency of a particular investment is high relative to the interest rate, financing or supplying firms often are reluctant to make loans if the capital return is highly variable or is likely to be consumed by the household sector. Hence, net income reflects both the internal and external financing restraints of the farm firm.

Consideration of some machinery as a "household" expenditure provides another basis for including net income in the investment equations. Farmers occasionally purchase additional machinery because of greater convenience or prestige, even though marginal returns are low. These purchases emphasize the complex interaction between the farm firm and household in the investment processes. The marginal efficiency of capital and the interest rate may have little influence on such purchases. Ability to pay for assets purchased mainly for "household" reasons depends heavily on net income. Again, past values of Y_F are likely to be an important decision variable for both the farmer and the external credit source.

Income is determined by prices, weather, technology and other influences which can be specified individually in the demand function. Ideally, it is desirable to include each component of Y_F separately in the demand function to determine the relative impact of each on the demand quantity. Because the least-squares model tends to degenerate with the resulting large numbers of variables and because the several series often are highly intercorrelated, it perhaps is desirable or acceptable to sacrifice some information on individual components of Y_F to gain a more accurate estimate of the total impact of Y_F on the demand quantity. Furthermore, the hypothesis that farmers focus attention on a few decision variables including net income rather than attempt to digest the implications of the myriad components of Y_F appears reasonable.

Equity

Assets, other than that represented by the particular resource, should be important in the resource investment function. Assets held in liquid forms, as cash reserves and government bonds, provide flexibility of input purchases. Also different assets are technically related; a "stock" of large power units may stimulate demand for four- or six-row planting, cultivating and harvesting machinery. Different types of assets also may be economically related, the farmer with a herd of cattle being better able to borrow funds for buildings and equipment.

The ratio of proprietors' equity to total liabilities has several impacts on resource demand in a dynamic agriculture. It is one measure of the farm firm's ability to withstand unfavorable outcomes. According to Kalecki's principle of increasing risk, the impact of an uncertain event is an increasing function of the firm's equity position.[14] A given financial loss may cause little concern if equity is high. But if equity is low, the same loss may increase liabilities above owned assets and cause bankruptcy. The equity ratio is a measure of this influence both psychologically for the farmer and actually for outside credit sources.

The equity ratio also reflects income represented by capital gains accrued on durable assets during periods of inflation. The equity ratio tends to increase in an inflationary period since liabilities ordinarily are fixed financial obligations not directly influenced by inflation. Capital gains serve as a source of equity and funds for investment, and it seems appropriate to include this influence in the investment function. Finally, the equity ratio also is a measure of all income-generating processes. Periods of high income provide an opportunity for farmers to pay debts and build equity. Hence, the equity ratio serves as a proxy variable for past income. Favorable income over several years tends to be reflected in the equity ratio because of the lagged adjustment of consumption and durable purchases to higher income.

Monetary Variables

Theoretically, the interest rate is a fundamental variable in demand functions for durable inputs. Yet, Meyer and Kuh state that "empirical findings...indicate that the interest rate is not important whether statistical inference, interviews, or questionnaires have been the method of investigation."[15] Logic and introspection suggest that the interest rate probably is overshadowed by other variables as a determiner of investment. It also is likely that many individual farmers have not invested to levels where the marginal efficiency of capital approaches the interest rate. More often the restraints imposed by "internal and external" capital rationing have provided the typical "upper bounds" on capital employment. Fluctuating weather and other stochastic elements cause the marginal efficiency of capital to vary widely, a consideration which may be of greater concern to farmers than is the interest rate. Empirical studies by Kendrick and Jones[16] and by Cromarty[17] suggest a

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[14] Kalecki, M. The principle of increasing risk. Economica (New series). 4:440-47. 1937.

[15] Meyer and Kuh. The investment decision, op. cit., p. 8. For earlier comments on the role of interest rates in investment see Henderson, H. D. The significance of the rate of interest. Oxford Economic Papers. 1:1-13. 1938.

[16] Kendrick and Jones, op. cit., p. 18.

[17] Cromarty, op. cit.; and Cromarty, William A. The farm demand for tractors, machinery and trucks. Journal of Farm Economics. 41:323-31. 1959.

secondary role for the interest rate in farm investment decisions. The study by Griliches,[18] however, indicates that tractor purchases are highly sensitive to changes in the interest rate. More research is needed to determine if this result arises because other trend variables (such as farm size, labor price, asset structure, the real prices of material capital items and technological changes) are correlated with trends in interest rates, causing difficulties of specification, or whether interest as the price of investment funds is singularly important.

Institutional restraints of lending agencies may be of greater significance than the interest rate in restraining loans to farmers. Tostlebe's study indicates that farmers have supplied the major share of the funds financing capital acquisitions.[19] But there is evidence that the externally financed portion of capital acquisitions is increasing.[20] Moreover, it may be argued that external capital sources have a significant marginal impact on investment. Because the external capital agencies of "marginal importance" are few, and because studies indicate that internal rather than external capital rationing is the greatest investment restriction,[21] the institutional restraints are not explicitly included in this study. Institutional restraints on credit are defined as factors other than the interest rate affecting the availability of funds from credit institutions. We believe, to a large extent, that influences affecting institutional credit restraints are reflected implicitly in the investment function through the income and equity variables discussed earlier.

Price Variables

As indicated previously, some price variables are implicitly included in net farm income. Prominent price variables which might be singled out for their hypothesized unique and prominent influence on investment are the own price of the durable item and the farm wage rate. The price of the durable item is likely to be particularly important in the short run. Even if equity, earning power and other financial variables are favorable, the final decision to purchase may be based on the

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[18] Griliches, Zvi. The demand for a durable input, op. cit.; and The demand for inputs in agriculture, op. cit. Another quantitative study, which indicates a significant response of farm mortgage credit to changes in the interest rate, is by Hesser, Leon F. The Market for Farm Mortgage Credit. Unpublished Ph.D. Thesis. Library, Purdue University, Lafayette, Indiana. 1962.

[19] Tostlebe, Alvin S. Capital in Agriculture: Its Formation and Financing Since 1870. Princeton University Press. Princeton, N. J. 1957. p. 21.

[20] Hathaway, Dale E. Trends in credit and capital. In Baum, E. L., Diesslin, Howard G., and Heady, Earl O. Capital and Credit Needs in a Changing Agriculture. pp. 81-96. Iowa State University Press. Ames. 1961; Hopkins, John A. Adequacy of credit for commercial agriculture in a growing economy. In Baum, E. L., Diesslin, Howard G., and Heady, Earl O. Capital and Credit Needs in a Changing Agriculture. pp. 247-54. Iowa State University Press. Ames. 1961.

[21] Heitz, Glenn E. Determinants of capital formation: Discussion. In Baum, E. L., Diesslin, Howard, and Heady, Earl O. Capital and Credit Needs in a Changing Agriculture. pp. 37-38. Iowa State University Press. Ames. 1961.

input price based on the farmer's belief that it is relatively high or low in terms of his experience. Once the input is purchased, the price is of historic interest only. Farmers need not be greatly concerned with expectations and future trends since ability to pay for the input does not depend on what happens to the price, once the durable is purchased. But the ability to pay for the input does depend on wage rates, operating input prices and farm output prices. These latter prices are more likely candidates for expectation variables. The farm wage rate might be singled out as a separate variable in the investment process because of the large substitution of capital for labor indicated in Figure 10.2. Past efforts to measure the influence of wage rates on farm investment demand largely have been unrewarding, however.[22]

The Accelerator

One argument for including a variable to represent an accelerator effect is based on an assumed fixed or "prescribed" ratio of output to durable capital. The decision by farmers to increase output could be realized in the short run by greater use of operating inputs. Given time to adjust durable capital, the previous prescribed ratio of durable capital to output would be restored according to the argument. Inclusion of an output variable in the investment function would accommodate this accelerator effect. Obviously, however, the causal relationship may be clouded, with greater output arising because of increased durable capital inputs, or durable capital extended to maintain the prescribed capital/output ratio.

The need for an accelerator variable depends on the resource investment structure being investigated. For farm machinery and buildings, the range of substitution with labor and operating inputs is large because of the technical characteristics of the inputs. Also, because many farmers tend to be overinvested in machinery in many instances and, as explained in Chapter 2, decrease in farm numbers allows the same or more output from a given stock of capital, a considerable increase in output could occur without increasing machinery inventories. Thus there appears to be no strong basis for inclusion of an accelerator variable for farm machinery demand.

The basis for the accelerator may be stronger for investment in livestock and feed inventories. The nature of these resources suggests there are few substitutes. In the short run, however, animals fed to heavier weights cause feed to be a substitute for animals. Farmers can increase output by selling breeding stock in the short run, but if output is to be sustained at the old level or at higher levels, the inventory level must be raised. A certain number of breeding stock and feed inventories are needed for a sustained output, and this ratio of

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[22] Cromarty, The demand for farm machinery and tractors, op. cit.; Griliches, The demand for inputs in agriculture, op. cit.; Kendrick and Jones, op. cit.

inventories to output is quite constant in the long run. The ratio, of course, has changed secularly somewhat as outlined in Chapter 4.

As mentioned previously, this logic may appear to be anachronistic, since it is expected that greater investment causes greater output. Undoubtedly, some elements of simultaneity are present and, in the absence of more sophisticated techniques, least-squares bias may be present in single-equation investment functions including an accelerator. Attempt to reduce the bias can be made by using lagged rather than current output as an explanatory variable in least-squares investment functions.

The relevance of first differences or original values to represent the accelerator influence has been debated. Kaldor has summarized several positions by different economists.[23] Our approach is pragmatic; we use the form giving most realistic empirical results. In several preliminary regressions, output and income variables were included both in first differences and original values. Without exception, the equations linear in untransformed, original data were more realistic and acceptable from a statistical and economic standpoint.

Other Variables

Additional variables that might be specified in the investment function include farm size, government programs and technological and other changes reflected in a time trend. A farmer acquiring additional land may work the added acres with the same capital equipment but with longer hours of labor and more operating inputs such as fertilizer, fuel, oil and repairs. But, given time, he may increase his capital stock of machinery, livestock and feed. Whether, as a result of farm consolidation, the final investment in assets is greater than the combined assets of different owners has not been finally established.[24]

Government programs may have contrasting elements of influence on investment demand. Acreage restrictions and marketing quotas would be expected to reduce demand for machinery. However, price supports also may improve the farmer's financial position and encourage investment. The net influence is not clear, although the short-run effect may be to reduce machinery demand.

Machine capital has indeed had its marginal productivity, and the marginal substitutability, raised by technical knowledge. A major portion of the basic farm machines, including the row-crop machinery and tractors, was in existence in the 1920's. But continual refinements of the basic machinery to provide greater versatility, convenience and productivity have increased the demand for durable assets. Knowledge of the productivity and profitability of improved investment items came

[23] Kaldor, N. Mr. Hicks on the trade cycle. Economic Journal. 61:833-47. 1951.

[24] Hoffman, Randall A., and Heady, Earl O. Production, income and resource changes from farm consolidation. Iowa Agr. Exp. Sta. Res. Bul. 502. Ames. 1962.

as a gradual process to farmers. These and other gradual influences can best be represented, although somewhat imperfectly, by a time trend variable in investment equations.

Single-Equation Estimates

Single-equation investment functions are generally used in the analysis which follows, although a few estimates are made by means of limited information techniques. We believe that the supply price of farm machinery and similar resources is determined primarily by variables in the nonfarm economy, and the resource price may be treated as exogenous in the farm investment function. If the supply of farm machinery and other durable assets is highly elastic as implied, the supply function need not be estimated simultaneously with the demand function. Specification of income and output variables in the demand function, as discussed earlier, may violate the monocausal structure. That is, income and output may be a function of investment and vice versa. Because some studies indicate the marginal product of machinery is low, and because services of durables are spread over the long run, additional investment is expected to influence output and gross income little in the short run. If this is true, least-squares bias may be small and the monocausal structure implied by a single-equation estimate may serve as a reasonable approximation of demand or investment functions. However, because of the contrary argument above, some demand functions are estimated by limited information. (The models examined in this chapter refer to single equations only.)

While a large number of variables could be specified in the investment function, the number must be reduced to a few important influences consistent with the estimational "capacity" of existing statistical models and available data. The judgment of what variables to include is based to some extent on the judgment of the researcher since selection cannot be based entirely on objective statistical tests: Several quite different specifications may give equally acceptable statistical results, and statistical inference may not allow differentiation among them. The investment function for machinery, for example, is specified as

$$(10.1)\quad Q_M = f(P_M/P_R,\ P_M/P_H,\ Y_F,\ E,\ S_p,\ S_M,\ A,\ r_S,\ G,\ T)\ .$$

The demand quantity (annual purchases or gross investment) is specified to be a function of the price of machinery, P_M, relative to prices received, P_R, and to wages of hired farm labor, P_H, net farm income, Y_F, the equity ratio, E, stocks of productive assets, S_p, stocks of machinery, S_M, farm size, A, short-term interest rate, r_S, government programs, G, and time, T. Not all of these variables, because of limitations from the data and methods used, can have a statistically significant effect on demand. Alternative equations then prove to be about equally efficient in predicting demand, and we are faced with making a selection.

EXPECTATION AND ADJUSTMENT MODELS OF INVESTMENT

The use of distributed lag models to express investment behavior appears appropriate for several reasons: First, expectations are important in determining the profitability and ability to pay for a durable asset. The principal expectation variable discussed earlier is net income, reflecting especially output prices and weather since they are least predictable. A somewhat different form of distributed lag model may arise if farmers are subjectively certain of the favorable price and financial conditions. A "psychologically" lagged adjustment to an equilibrium or desired quantity may result if farmers adopt a wait-and-see attitude, postpone purchase because of inertia of past decisions, etc. Other influences causing lagged adjustments are institutional restraints posed by laws and customs. External restraints arising from inadequate repair facilities in earlier days, or from waiting until neighboring farms can be purchased to obtain an economic unit for use of larger machinery, also result in adjustment lags.

One of the prominent features of modern econometric research is the emphasis on simple, structural equations providing information about long-run and short-run coefficients, adjustments, expectations and other information. Various types of statistical distributed lag models may be devised to approximate the actual farm investment function. Each has unique advantages, depending on the nature of the "true" function, but none of the models possesses all the properties desired in a general model. It is useful to consider several of these models and base the final choice on the basis of empirical results in later chapters as well as on a priori considerations.

Model A

The most general demand model is formed by allowing the parameter estimates of lagged variables to be unrestricted. It is useful to assume that the true model is linear in the parameters, but the estimated parameters of the lagged variables need not be forced to decline at a linear or geometric rate. Model A, used later in this study, is of that form. Expected income, Y_F^*, is a function of past income:

$$Y_{Ft}^* = a + b_1 Y_{Ft-1} + b_2 Y_{Ft-2} + \dots + b_n Y_{Ft-n}. \tag{10.2}$$

To form model A, the demand quantity or stock is considered a function of expected income, the ratio of machinery price, P_M, to prices received by farmers, P_R, time, T, and error, u. The least-squares estimate of model A is formed by substituting the right side of (10.2) for Y_F^* in the demand equation (10.3).

$$Q_{Mt} = a + bY_{Ft}^* + c(P_M/P_R)_t + dT + u_t. \tag{10.3}$$

The advantage of model A is that no assumption is made of the magnitudes of the coefficients of lagged income, but practical statistical considerations such as loss of degrees of freedom and multicollinearity limit the number of coefficients which may be estimated with reliability. We can continue to add lagged variables until the coefficients of the additional variables are nonsignificant, or the adjusted R^2 falls, and/or the regression coefficients become unstable. While it is impossible to determine if an additional variable fails to improve the equation, because of statistical problems or because the true farm decision function does not include the variable, we do estimate some forms of model A in subsequent chapters.

If model A is the appropriate demand function, an autocorrelated error structure arises if the distributed lag is not accommodated in the estimation process. If model A is correct and a model is estimated by least squares with income lagged only 1 year, the effect of Y_F on purchases for the remaining n-2 years becomes part of the unexplained residual. The error would not be distributed randomly, but would display positive autocorrelation since the lagged values of Y_F are autocorrelated and exert a consistent positive influence on Q_M.

Model B

A second and somewhat similar distributed lag model of machinery demand is formed by selecting a dependent variable resulting from the income generating process. The variable E, the ratio of farm proprietor's equity (owned assets) to liabilities on January 1 of the current year, is assumed to be a function of farm income in the past n years:

$$(10.4) \qquad E_t = a + b_1 Y_{Ft-1} + b_2 Y_{Ft-2} + \dots + b_n Y_{Ft-n}.$$

As mentioned previously, E may be used as a proxy variable for Y_F^*. The demand model B, formed by substituting E_t for the expected income in equation (10.3), is:

$$(10.5) \qquad Q_{Mt} = a + bE_t + c(P_M/P_R)_t + dT + u_t.$$

If E_t is a realistic indication of expected income, as purely under capital gains, models A and B are equivalent. The advantage of model B is that only the single variable E_t needs to be included in the least-squares regression to represent the lagged income and other effects discussed earlier. But this equation has a type of leakage since information on the b_i values in equation (10.2) is lost. An estimate of these can be provided from a least-squares estimate of equation (10.4). While the equity ratio is an indicator of current financial position to farmers and credit institutions, as a measure of ability to finance a durable asset and to reflect capital gains from inflation, E is not a realistic indication of past net income if current income is wholly spent for consumption goods.

Model C

If the number of lagged income variables in model A is large and a useful proxy variable is not available, expected income may be represented by making assumptions about the values and distribution of the b_i's in equation (10.2). Expectations may be most heavily influenced by recent variables, the influence of past variables declining at a linear rate. Using this condition, and assuming current income expectations are formed from income of only the past n years, expected income is

$$(10.6) \qquad Y^*_{Ft} = a + b\left[\frac{nY_{Ft-1} + (n-1)Y_{Ft-2} + \dots + Y_{Ft-n}}{\sum_{i=0}^{n}(n-i)}\right].$$

If n = 3, we may write equation (10.6) as

$$Y^*_{Ft} = a + b\left[\frac{3Y_{Ft-1} + 2Y_{Ft-2} + Y_{Ft-3}}{6}\right].$$

Model C is formed by substituting the variable in brackets for expected income in equation (10.3). We can experiment with several values of n and choose the appropriate value on the basis of the R^2 or other criteria. The distribution need not, of course, be restricted to the linear form illustrated in (10.6). More imaginative forms, such as a distribution forcing the b_i's to decline at a geometric rate, might be employed. A distribution declining by equal decrements as in equation (10.6) has intuitive appeal since data imperfections may prohibit isolation of a more realistic form.

Model D

The generalized Working method, a linear long-run equilibrium model proposed by Ladd and Tedford, which we slightly modify as a machinery investment function, can be expressed as

$$(10.7) \quad Y^*_F = a + b_1Y_{Ft-1} + (b_1 - k)Y_{Ft-2} + \dots + [b_1 - (n-1)k]Y_{Ft-n}$$

where k is the annual decline of the income coefficients.[25] When $b_1 - (n-1)k=0$, no additional terms need be added. Simplifying terms, (10.7) becomes

$$(10.8) \qquad Y^*_F = a' + b_1Y_{AFt-1} + kY_{WFt-1}$$

where Y_{AF} and Y_{WF} respectively are simple and weighted averages of

[25] Ladd, George W., and Tedford, John R. A generalization of the Working method for estimating long-run elasticities. Journal of Farm Economics. 41:221-33. 1959.

past income. Substituting the right side of equation (10.8) for expected income in equation (10.3), model D is formed.

Model D has this chief disadvantage: the year t-n, when income no longer influences current expectations, is not determined explicitly by the model. In application, model D can be estimated with average and weighted income variables with increasingly greater lags, and the magnitude of the adjusted R^2 might be used as the criterion for final selection of the appropriate n.

An advantage of model D is that only two variables need be used to represent expected income, hence the model is suitable for least-squares estimation. If b_1 and k are positive and significant, the coefficients of lagged income decrease by equal decrements k, and models C and D essentially are equivalent. Model D allows more flexibility in determining the nature of the income lag, however. If k is zero and b_1 is greater than zero, the model implies that income expectations are influenced equally by n past incomes and not at all by income beyond n. The income expectation can be represented by a simple average of n past incomes, Y_{AF}.

Model E

If the expected change in income is proportional to the error made in estimating income last year (the difference between actual income and expected income last year), another type of expectation model is generated.[26] (See Chapter 3.) The model, expressed mathematically, is

$$(10.9) \qquad Y^*_{Ft} - Y^*_{Ft-1} = e(Y_{Ft-1} - Y^*_{Ft-1})$$

where e is the expectation coefficient. If we solve for current expected income, Y^*_{Ft}, then for Y^*_{Ft-1} in the basic demand equation (10.3) and substitute these values into the expectation equation (10.9), the following model E is formed:

$$(10.10) \quad Q_{Mt} = a' + beY_{t-1} + c(P_M/P_R)_t - c(1-e)(P_M/P_R)_{t-1} + deT + (1-e)Q_{Mt-1} + u_t - (1-e)u_{t-1}.$$

The error structure in equation (10.3) must be quite complicated if autocorrelation is to be absent in (10.10). Two estimates of 1-e are available — from the lagged quantity and lagged price. Model E is sometimes approximated in least-squares analysis by omitting the lagged price variable. The value of e is assumed to lie between zero

[26] Nerlove, Marc. Distributed lags and demand analysis for agricultural and other commodities. USDA Handbook 141. 1958; Nerlove, Marc. The Dynamics of Supply. The Johns Hopkins Press. Baltimore. 1958.

and one, and implies that the influence of successively distant prices declines at a geometric rate but never reaches zero.

Income may not be the only expectation variable in the demand function. The extent of modification of model E to accommodate other expectation variables depends on the nature of the respective expectation coefficients. If the expectation coefficient is the same magnitude for all variables, the model becomes comparable to the following adjustment model F. This situation is very unlikely, however.

Model F

The previous demand models basically have been expectation models whereby farmers are assumed to base purchases on expected net income. Model F is an adjustment model, the basic assumption being that farmers are subjectively certain of the current explanatory variables in demand equation (10.1), but adjust purchases slowly to desired levels because of the psychological, institutional or other reasons. For numerous resources, it is reasonable to assume that the greatest adjustment is made towards the desired or equilibrium level of purchases in the early years. As the equilibrium level is approached, annual adjustments become very small. A model of demand proposed by Nerlove is based essentially on these conditions.[27] The actual adjustment in purchases in year t is a constant proportion, g, of the difference between the desired or equilibrium level of purchases in the current year, Q^*_{Mt}, and the actual purchases during the past year:

$$(10.11) \qquad Q_{Mt} - Q_{Mt-1} = g(Q^*_{Mt} - Q_{Mt-1})$$

or

$$Q_{Mt} = gQ^*_{Mt} + (1-g)Q_{Mt-1}.$$

The equilibrium quantity is a function of income, prices and time, or

$$(10.12) \qquad Q^*_{Mt} = a + bY_{Ft-1} + c(P_M/P_R)_t + dT + u_t.$$

The term u_t is the residual in year t. Substituting the right side of (10.12) for Q^*_{Mt} in (10.11), model F is

$$(10.13) \qquad Q_{Mt} = ag + bgY_{Ft-1} + cg(P_M/P_R)_t + dgT + (1-g)Q_{Mt-1} + gu_t.$$

Coefficients in the model may be estimated by least squares. The single estimated coefficient of Q_{Mt-1} is 1-g, from which the adjustment

[27] Nerlove, Distributed lags and demand analysis, op. cit.

coefficient g may be found. The coefficients of the price and income variables are short-run coefficients. The long-run coefficients b and c in equation (10.12) are found by dividing the coefficients estimated in equation (10.13) by g. Variables included in model F are similar to those in model E, but the error structure in model F is somewhat less complicated. Thus, single-equation least squares is a more satisfactory estimational procedure if the adjustment model F rather than the expectation model E is appropriate. It is possible to combine expectation and adjustment models E and F into a single equation, but the necessary modifications tend to reduce the reliability of the coefficients estimated by least squares from time series.[28] If expectations and adjustments are both essential in the investment function, any one of several expressions from equations (10.2), (10.4), (10.6) or (10.8) might be substituted for Y_{Ft-1} in model F.

If a desired level of annual investment rather than stock is the goal of investment behavior, equation (10.13) is appropriate in the given form. But if a desired level of stock is the goal of investment behavior, then machinery stock S_M might be substituted for Q_M in the model F, or the following adjustment models might be used.

Model G

Conceptually, a principal basis for input purchases in agriculture is a subjective farm production function. Machinery inputs are an important resource in the production function, and the equilibrium or desired level of machinery input may be more nearly identified as the total stock of machinery than as annual gross investment. Investment in machinery during the current year then may be a function of the desired level of machinery inventory since machine services are distributed over several years, not only the year of purchase. Griliches proposes an adjustment model based essentially on this argument.[29] The actual adjustment in machinery inventories during year t is some proportion, g, of the desired or equilibrium change in inventories. The adjustment to the desired machinery stock is made gradually. Mathematically, the adjustment model is

$$S_{Mt+1} - S_{Mt} = g(S^*_{Mt+1} - S_{Mt}) \tag{10.14}$$

where S_{Mt+1} and S_{Mt} are machinery stocks on January 1 of year t+1 and t respectively. S^*_{Mt+1} is the desired or long-run equilibrium stock of machinery on January 1 of year t+1. Depreciation is assumed to be a constant proportion, h, of beginning year stocks. Equation (10.15) is an identity, indicating that

$$S_{Mt+1} = Q_{Mt} + (1-h)S_{Mt} \tag{10.15}$$

[28] Ibid., pp. 59-60.

[29] Griliches, The demand for inputs in agriculture, op. cit., p. 314.

stocks at the end of the year equal investment plus undepreciated carry-over from last year. Rearranging terms, we may write (10.15) as

$$(10.16) \qquad Q_{Mt} = (S_{Mt+1} - S_{Mt}) + hS_{Mt} \, .$$

Assuming the desired level of stocks, S^*_{Mt+1}, is

$$(10.17) \qquad S^*_{Mt+1} = a + bY_{Ft-1} + c(P_M/P_R)_t + dT + u_t$$

and substituting the right side of (10.14) for the term in parentheses in equation (10.16), an investment model, G, is formed.

$$(10.18) \qquad Q_{Mt} = ag + bgY_{Ft-1} + cg(P_M/P_R)_t + dgT + (h-g)S_{Mt} + gu_t$$

The long-run coefficients b, c and d cannot be determined directly from model G because the values of h and g are not known. Although the values of g in (10.13) and (10.18) are not strictly comparable, the estimate from (10.13) (with S_M rather than Q_M the dependent variable) might be used to determine the long-run coefficients in equation (10.17). Also, a previous estimate of the rate of depreciation, h, is sometimes available. If so, g can be found from the least-squares coefficient (h-g) of beginning year stocks in equation (10.18).

Model G has several advantages. It explicitly recognizes machinery stock as an important variable in the investment process. The dependent variable, however, is annual investment Q_{Mt}, a more volatile and sensitive quantity. We are "explaining" considerably more if the annual investment, rather than total stock, is selected as the dependent variable. Furthermore, the error structure is not particularly complicated. A disadvantage of the model is the failure to identify separate values of h and g.

Model H

It is possible to formulate an investment function using the assumptions underlying model G, but which provides estimates of g and h.[30] A slight modification is made in equation (10.17), though it is not necessary in the formulation. Since current income may influence investment, equation (10.17) is modified to form equation (10.19).

$$(10.19) \qquad S^*_{Mt+1} = a + bY_{Ft} + c(P_M/P_R)_t + dT + u_t$$

Using the assumptions embodied in equations (10.14), (10.15) and (10.19), the following investment model, H, is derived where B = bg,

[30] Nerlove, Distributed lags and demand analysis, op. cit., pp. 86-93.

$C = -bg(1-h)$, $D = cg$, $E = -cg(1-h)$ and $F = dgh$. The residual V_t is $gu_t - g(1-h)u_{t-1}$, implying that equation (10.19) must follow a very complicated autoregressive pattern for V_t to be distributed randomly.

$$(10.20) \quad Q_{Mt} = A + BY_{Ft} + CY_{Ft-1} + D(P_M/P_R)_t + E(P_M/P_R)_{t-1} + FT + (1-g)Q_{Mt-1} + V_t$$

Assuming equation (10.20) is estimated by least squares from data transformed into logarithms, the following price elasticities of demand may be computed: for the short run (first year), D; for the intermediate run (two year), D + E; and for the long run, D/g = c. Similar estimates can be made of the elasticity with respect to Y_F. The value of the adjustment coefficient g can be readily estimated from the coefficient of lagged Q_M. Model H is overidentified and provides two estimates of the depreciation rate: $h = (C + B)/B$ and $h = (E + D)/D$. Nerlove suggests that the coefficients of the variable measured most accurately be used to estimate g. Given the value of h and g, the value of d may also be computed.

Model H is potentially useful because of the extended information provided by the coefficients. Its chief disadvantage is the frequent occurrence of lagged variables which tend to be highly correlated with current values in economic time series. Also the error structure is somewhat foreboding. Model H may be revised to conform with the investment specification of equation (10.17), rather than of equation (10.19), merely by lagging Y_F one year in each of the income variables in equation (10.20).

Model I

The investment model G may be modified slightly to allow determination of the adjustment coefficient g. Defining ΔS_{Mt} as $S_{Mt+1} - S_{Mt}$, equation (10.14) may be written as $\Delta S_{Mt} = gS^*_{Mt+1} - gS_{Mt}$. By substituting the expression for desired stocks from (10.17) into (10.14), model I (10.21) is formed.

$$(10.21) \quad \Delta S_{Mt} = ag + bgY_{Ft-1} + cg(P_M/P_R)_t + dgT - gS_{Mt} + gu_t$$

Model I, essentially a Koyck model, is model G with an adjustment of the dependent variable for depreciation.[31] This is obvious if we rewrite equation (10.15) as $\Delta S_{Mt} = Q_{Mt} - hS_{Mt}$ where net investment is equal to gross investment less depreciation. The advantage of model H is that it can be easily estimated, all coefficients are identifiable and the error structure is relatively uncomplicated. Model I is advantageous when estimates of investment stock S_M are available and annual investment

[31] Koyck, L. M. Distributed Lags and Investment Analysis. Contributions to Economic Analysis. North-Holland Publishing Company. Amsterdam. 1954.

Q_M are unavailable. The dependent variable in model I is computed by taking first differences of S_M. After estimating the coefficients in model H by least squares, the short-run and long-run coefficients may be computed. It is possible, of course, to predict ending year stocks from the predicted change in stocks, $\Delta S'_{Mt}$, i.e.

$$S'_{Mt+1} = \Delta S'_{Mt} + S_{Mt} \ . \qquad (10.22)$$

If the rate of depreciation h is known from other sources, gross annual investment Q'_{Mt} can be predicted as

$$Q'_{Mt} = \Delta S'_{Mt} - hS_{Mt} \qquad (10.23)$$

and may be a useful approximation if h tends to be relatively constant.

An approximate description of the investment process depicted by models G and I aids in evaluating the coefficients of the models. Assume that product prices P_R increase 1 percent and that Y_F consequently increases 2 percent. According to the models, the first short-run effect is to reduce the real price of machinery, P_M/P_R, thereby encouraging some investment. Since expected income is based on past income variables, the farmer waits a year or more until he believes the income rise is "permanent." He then raises Q_M to the desired amount. In the intermediate run, after he has become subjectively certain of a favorable future income, he raises annual investment Q_M to the level necessary to reach the desired level of stock at the rate specified by the adjustment coefficient g.

The complete adjustment of annual investment is made long before the desired level of stock is reached in most instances. When the maximum response or long-run elasticity of annual investment to P_R is achieved, the response of stock to P_R is only partially complete and is called the "intermediate-run" elasticity. Three phases of stock elasticity with respect to P_R are apparent: (a) the short-run response with respect to $-P_M/P_R$, (b) the intermediate response with respect to (a) plus the P_R component of expected net income completed when Q_M reaches the desired level and finally (c) the long-run response completed when the adjustment to the desired level of stock is achieved. The desired level of stock is reached when the inventories no longer grow, i.e. when $Q_{Mt} = hS_{Mt}$. Depreciation has reached a sufficient level to consume annual gross investment.

Model J

Under different assumptions, structural models such as I may be identically specified but with alternative interpretations of the coefficients. Assume that farmers are unconcerned about stock levels but only derive satisfaction from the purchase of new machinery. Further assume that they adjust immediately to this satisfactory level of purchases when they become subjectively certain on the basis of past year income that earnings will be favorable for purchasing the input. The demand equation is correctly specified as

$$(10.24) \qquad Q_{Mt} = a + bY_{Ft-1} + c(P_M/P_R)_t + dT + u_t .$$

Suppose that the right side of identity equation (10.15) is substituted for Q_{Mt}

$$(10.15) \qquad Q_{Mt} = \Delta S_{Mt} + hS_{Mt}$$

in equation (10.24). The resulting equation, after rearranging terms is

$$(10.25) \quad \Delta S_{Mt} = a + bY_{Ft-1} + c(P_M/P_R)_t + dT - hS_{Mt} + u_t .$$

The phenotypes (variables included in the least-squares equations) of models I and J are exactly alike. But the genotypes (true structure) of the two models are quite different. Without a priori knowledge of the investment structure, it is difficult to interpret the coefficients correctly. The model dramatizes the need for caution in interpreting the results of structured equations. Interpretation of the coefficient of lagged stock as the depreciation rate h (model J) when it actually is the adjustment rate g (model I) would be disconcerting indeed. Surprisingly, this does not necessarily lead to ambiguity in interpreting the short- and long-run price and income elasticities. The short-run coefficient of stock with respect to $(P_M/P_R)_t$ in model I is the least-squares coefficient of the price variable in equation (10.21). The long-run coefficient is the short-run coefficient divided by the adjustment rate g.

For model J, the short-run coefficient of stock with respect to $(P_M/P_R)_t$ again is the least-squares coefficient of the price variable in equation (10.25). Determination of the long-run coefficient is more subtle, however. In the long run, the equilibrium level of stock S^*_{Mt+1} is reached when

$$(10.26) \qquad S^*_{Mt+1} + S_{Mt} ,$$

that is, when net additions to stock become zero, or

$$(10.27) \qquad \Delta S_{Mt} = 0 .$$

On the basis of equation (10.27), the right side of equation (10.25) is equated to zero, and the long-run equilibrium level of stock occurs when

$$(10.28) \qquad a + bY_{Ft-1} + c(P_M/P_R)_t + dT = hS_{Mt} .$$

Substituting the equilibrium stock relationship from equation (10.26), and dividing through by h, the expression for equilibrium stock is

(10.29) $$S^*_{Mt+1} = \frac{a}{h} + \frac{b}{h} Y_{Ft-1} + \frac{c}{h} (P_M/P_R)_t + \frac{d}{h} T .$$

It follows that for model J, the long-run coefficient of stock with respect to price is the least-squares coefficient of the price variable divided by the least-squares coefficient of the lagged stock variable. This is exactly the same coefficient and procedure as used for computing short- and long-run price responses from model I. Despite the different form of the equations, the estimates of price and income responses are the same. Less emphasis, therefore, need be given to determining whether model I or J is appropriate.

Numerous other models of value in explaining investment behavior could be presented. For example, adjustment and expectation models might be formulated with ending year stock as the dependent variable. In most of the analysis which follows, however, we select to explain net or gross annual investment. This approach better relates to farmer decision processes and variables important to them in defining the structure of agriculture. We are, of course, interested in eventual explanation of the resource structure of agriculture. If we have information about the parameters determining quantities in annual investment equations, inferences can be made about total stock by use of models such as G, H and I.

Most of the models explained above are modified in the process of estimation in the quantitative analysis of later chapters. Perhaps the most successful models are those resulting from relatively simple expectation models, such as those in equation (10.2), (10.4), (10.6) and (10.8) combined with adjustment models G and I. The terminology used in subsequent chapters generally refers to the models outlined in this chapter.