Tractors

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FACULTY OF ECONOMIC AND SOCIAL STUDIES

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AN ECONOMETRIC ANALYSIS OF THE DEMAND FOR FARM TRACTORS

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The Demand for Farm Tractors in the U.K. - An Econometric Study over the Period 1948-1965

1. Introduction

Over the past 15 years there has been much empirical investigation into the influences affecting investment decisions by the private producing sector of the economy. These are relevant to policy making, through the quantification of these influences, and to economic theory, through formulation and testing of investment hypotheses. The latter is relevant, through its implications to theory of the behaviour of the firm. However, as emphasised by Eisner and Strotz (1) many problems still remain. Firstly, there is the theoretical problem that a gap still remains between economic theory and the various proposed empirical bases to investment - particularly with regard to the position of expectations. Secondly, there is a divergence between the determinants of investment when looking at different levels in the economy - total economy versus industry versus firm. Further there is a divergence between industry and industry (this is also emphasised by Chenery (2)).

The majority of empirical studies have been at the economy level or at the industry level and have looked at the time rate of increase of capital assets as a whole. That is, they have been concerned with total demand for durable capital goods at either level - they have not been concerned with a single particular input. For example, De Leeuw (3) studied the demand for capital goods by manufacturers in the U.S. economy; Gehrel and Wiggins (4) fixed capital investment in manufacturing. Very few studies have looked at the disaggregated investment of an industry or sector. An exception is a cross-section study by Klein (5) into the demand for railraod cars and track by U.S. railroads. However such disaggregation of investment may prove to be worthwhile from both an empirical and a theoretical standpoint. Thus it is to be expected that some of the influences affecting investment in one input, say farm machinery, may be quite different from those affecting investment in another, - say farm buildings. A disaggregated study can evaluate these effects more specifically - for example in Klein's study (5) age of railroad cars was a significant variable in his cross-section investment function. Secondly, certain investment theories may be expected to have more relevance to a certain type of capital input than others and may be very consistent with the demand for that input. On aggregation this specificity may be lost. Thus, demand for a certain type of input may emphasise capital widening - the accelerator-type hypothesis; another, capital deepening; another, traditional profit maximising theories. An argument can be made against disaggregation in that competition between projects for capital will influence the individual investment functions; that is the investment function for one durable input is not independent when faced with a capital constraint. However it seems worthwhile to investigate the determinants of investment in specific durable inputs to see if this is a problem. In fact a multiequation model of investment allowing for this possible simultaneity problem would be ideal; with a budget constraint of profit, credit and liquid assets.

The majority of empirical studies have also been concerned with the manufacturing side of the private producing sector; typically with the whole sector as opposed to individual industries. Siblings of the manufacturing sector, such as agriculture, have not as yet been investigated at all thoroughly. However, it seems important to do so since conclusions from the studies on manufacturing industries cannot be applied ad hoc to other industries because of differences in industry structures. Thus, for example, studies on manufacturing industries emphasise the influences of corperate saving and of the dichotomy between ownership and management on investment (see Kuh (6)). Farming however is still an industry of entrepreneurs operating under relatively perfect competition (except for ease of entry) and with no control over prices. Such studies that have been carried out into the demand for durable capital inputs in agriculture - Griliches (7), Cromarty (8) - emphasise different findings. However further work is needed, especially as these studies relate to U.S. agriculture which has a somewhat different structure to U.K. agriculture. Both studies can also be criticised conceptually, in that they ignore the problem of quality change of the input over the time period studied.[1]

As well as being an investment study, a demand study for tractors investigates demand for a capital input per-se under an oligopsonistic marketing structure. There has been some study on the oligopolistic supply situation in agriculture but there has been little work done on the relationship between farmers and the suppliers of capital inputs. (Although there has been many studies on the demand for durable consumer goods in an oligopsonistic market - for example Suits (9).) In the market for new tractors 5 firms supply 95% of the market and there is recognised brand loyalty. Further because dealers are tied to their respective suppliers the practice of discounting does not give rise to much price competition. In investigating the demand for new tractors there should be a feedback of information on the market structure involved in their demand and supply. For example, the effects on total sales of advertising expenditure and of model changes

1. Heady and Tweeten (in Resource Demand and Structure of the Agricultural Industry by E.O. Heady and L.G. Tweeten, Iowa State University Press, Ames 1963) have taken some account of quality in a demand study for fertilisers but their studies on durable capital inputs ignore the quality problem.

is looked at in this study.

A demand function for tractors has relevance also to more specific problems. One such problem is that of finding out why farmers buy tractors. Do they simply want a tractor unit; irrespective (within limits) of its horse-power? Do they buy on the grounds of potential draught power only? Do they want a tractor unit which provides a range of services in addition to those of provision of draught power and of vehicular characteristics? Experimentation with different ways of expressing the investment variable in the demand function may help in understanding this problem. It is further important in looking at the future trend of demand - will it be for more horse-power per unit, as opposed to an emphasis on units incorporating new technical advances in design; or simply for an increased number of units of the same quality?

Secondly, government action has been very prevalent in agriculture over the period. In so far as this action - in particular through investment allowances and price support - has affected the demand for tractors then it has also affected output and employment in another sector of the economy. Hence the study allows some investigation of the effectiveness of policy on agriculture per-se and its side effects on another industry. There may also be some effect on the export market for new tractors. In the short run if home demand is encouraged, exports may be restricted; in the long run both may be encouraged by this governmental stabilising influence in Agriculture. Government action may also have been an influence via another sphere of activity. Farmers depend mainly on banks for their credit especially short and medium term credit. Thus, for example, in 1955 total advances by banks to British agriculture were £230 million (10) whilst credit from other sources, excluding merchant's credit (which is extended for non-durable inputs) and private sources, was only £29 million (11). Private sources were also important - being estimated at £200 million (11); hence it may be expected that in so far as tractor purchases are affected by credit availability they will be affected chiefly by the availability of private and bank credit. This is further emphasised by the fact that only a small proportion of new tractors are purchased by hire purchase (less than 10% (12)) and there has been little variability from year to year in the absolute number.[1] Thus if interest rate policy, as practised by the government, is effective it could have a direct effect on the demand for tractors.

Finally, in so far as this study can estimate the structural relationship underlying the demand for tractors then it is relevant to the problem of estimation of future demand and diagnosing a change in the present trend. Further, the allowance to be made for error from the stochastic influence can be directly assessed. The structural relationship is also relevant to the problem of estimating aggregate agricultural supply when coupled with information about other factor markets.

Briefly, this study attempts to estimate investment functions underlying the demand for a single durable input - wheeled farm tractors; a major part of the total capital input in a single industry - U.K. agriculture. Estimation is by regression analysis using annual data from 1948 through to 1965. As a corollary other problems such as the effects of policy action on tractor demand, the market structure for new tractors and the prediction of future demand are also looked at.

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1. See Appendix B. (i).

2. The Theoretical Framework

As pointed out by Kuh (6) empirical studies on investment behaviour have to marry two quite distinct theoretical approaches. Firstly, we have the equilibrium theory of capital which sets out the conditions determining the optimal capital stock. Secondly, we have accelerator type hypotheses which explain the rate of change of the capital stock, using the optimal level of stock as a datum. Thus the first theory does not account for the adjustment process, the second does not explain the optimising basis. Both theories are conceptually important to any investment study; their relative importance must be related to the particular level of investment under discussion. Their relative importance to this study may be assessed by adapting Meyer and Kuh's (13) definition of the three motives (economic, technical and prestige) underlying investment decisions - since we are concerned with a single industry made up of many individual decision makers.

Particularly since we are dealing with an industry composed of many entrepreneurs, operating under a competitive market structure, the profit motive would seem important. The theory of the firm then says that the stock of machines should be increased, until the present discounted value of future earnings from the last machine equals the price of the last machine to be purchased (assuming all the machines to be identical) in order to maximise profits. Recognising that capital inputs are 'lumpy' whilst analysis deals with a continuous case then the optimum position is that closest to this definition. This is then a definition of the optimum stock for the firm recognising that future earnings (the prospective marginal revenue product) arises from the services provided by the machine and that these earnings should be discounted to the present time. This approach thus indicates that the important influences determining the optimum stock of machines for the firm are the expected earnings accruing from the use of the machines, the rate of interest and the price of the machines. If we consider that the firm is not at the optimum position but is adjusting towards it, then three other influences are important from the profit maximising theory of the firm. Firstly, the above analysis assumes a diminishing marginal revenue product (because of declining marginal physical productivity) as the stock of machines is increased. Hence existing stock exerts a depressing effect on the adjustment process and hence on new investment (except as the services available from stock fall by depreciation). This is further important if the firm faces a capital constraint and there is competition between various investment projects. Secondly, increasing quality of the average machine used means the marginal revenue product curve is shifted upwards as marginal physical productivity from use of the input is increased. Thirdly, the profit maximising theory of the firm is also concerned with the relative demand for all inputs : inputs should be increased until relative marginal revenue products are equal to relative prices. Changes in relative prices then involve substitution of inputs; for example, capital deepening involves substituting capital for labour as the price of labour rises relative to that of capital.[1] The theory of the firm thus indicates six variables determining the optimum stock of tractors at the firm level. At the aggregate level, relative prices, the rate of interest and changing quality of the input still exert the same influence in that they are influences external to the firm. Prospective earnings and stock, however, are variables at the firm level. On aggregation, and particularly in this case, it

1. Conceptually the cost of capital relative to that of labour should be the total variable cost - running costs, interest payment, repair and depreciation. However, depreciation, interest payment (and to some extent running costs) are proportional to purchase price of the machine and this is used in price ratios, being a more convenient measure. The size of future repair bills are very susceptible to the stochastic influence and should be ignored.

may be that prospective earnings are less important than at the firm level - unless there is a general trend for all firms. Thus agriculture is a heterogeneous industry, with regard to the variety of commodities produced, and further some firms may be increasing in profitability, others decreasing in profitability within the same farm classification; hence the effects of this variable may tend to cancel out. Secondly, because tractors are, as mentioned, a 'lumpy' input then it is likely that because the optimum cannot be exactly obtained, overinvestment will occur at the firm level. This is particularly likely because there tends to be a seasonal demand for tractor services leading to a stock above the economic optimum as looked at from an annual viewpoint. If this is so then at the aggregate level the depressing effect of stock on future investment should be less intensified compared to the firm level.

A second motive, relevant to the accelerator hypothesis, is the technical motive; usually associated with capital widening or a lagged investment response to an output change. A priori this influence does not seem as important with respect to this particular input as it is with respect to total investment in manufacturing industries. Firstly, tractors are related to scale as defined by acreage - at the aggregate level this is practically fixed (although the available acreage has declined marginally over the period). Secondly, output from acreage is a function of a level of inputs and weather. Hence agricultural output changes as revelant to demand for tractors, are probably related more to these two than to capacity, whereas in manufacturing industry the variable input level is relatively fixed; there are fewer exogeneous influences and output is related very much to capacity. However it is possible that accelerator type reasoning may be applicable through three other influences. Firstly at the firm level, the number of farms has declined over the period of study, and the average acreage of each farm has risen. In so far as this allows for mechanisation and means a greater demand per acre for tractor services this would encourage demand.

However, it could have the opposite effect if on the average it meant that tractor capacity was now more fully utilised. Secondly, changes in the output mix could affect demand for tractor services - more specifically a swing to cash crops away from livestock could create a need for increased tractor services. A third influence arises from the already mentioned, seasonal demand for tractor services. Two seasonal peaks of demand occur - autumn and spring, particularly the latter. The two are interrelated to some extent, in particular the spring peak is increased if the previous autumn peak does not reach its planned level. This may happen through the influence of weather, specifically in September, October, November and December. Hence this weather may have a short term influence on the technical demand for tractor services the following spring.

A third motive can be defined as the prestige motive. This may be adapted to this context in that it may influence the replacement rate of old tractors by new. Associated with this we may look at the tractor as being, in part, a consumption good. A large proportion of farms in the U.K. are family farmed and increasing tractor services provide utility by increasing available leisure time since they reduce hours of work necessary to complete many farm tasks. This especially applies to total available services, for example horse-power, as opposed to numbers of tractors. This consideration is likely to lead to overinvestment, perhaps by increasing the rate of replacement, beyond that which is economically optimum. Given that the marginal utility of leisure has changed over time then this degree of overinvestment will have changed also. However, the profit motive imposes a constraint on how far this utility desire can be obtained. Thus the level of profits objective determines the degree to which the desire is satisfied, particularly as tractors are a large item of expense in the farm budget.

Financial influences can also be looked at as determenants of when adjustments, by investment, are made toward the optimum level of stock, as determined by the prevailing economic forces. Credit availability particularly would seem important - both internal and external to judge by the sources of credit to agriculture as diagnosed by Chevely and Price(11). Internal credit availability may be judged by past profit levels; the cost of external credit by the rate of interest charged by the banking system.[1] Further it is usually indicated that there is some correlation between the level of bank rate and the availability of bank credit. Capital rationing may be particularly important due to the fact that the majority of farms in the U.K. are owner occupied. Miller(14) has pointed out that owner occupied, as compared to tenant farmers, do not reach the optimum combination of resources with respect to the capital input -- presumably due to capital shortage. However, since we are considering investment in a single input, not investment as a whole, this influence is probably affected by competition between projects for investment; particularly by investment in closely related projects such as investment in other farm machinery. Because of lack of relevant data and time this study has not attempted to look at this through a multiequation model. A second possible financial influence is that of tax considerations, in particular capital allowances for income tax relief. As shown by Dunford and Richard (15) only the investment allowance (as formerly given) provided the claimant with a tax concession over and above the market rate of depreciation, since it is not deducted in determining the written down value. Investment allowances for new machinery were first introduced in 1954 at 20%; discontinued for three years and then reintroduced until 1966 when the system was altered. These allowances may have led farmers to undertake the replacement of machinery in advance of the time they would otherwise have chosen (15). It may also encourage them to move more quickly toward the desired stock level.

Theory therefore, with reference to the specific input being considered, would

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1. As previously mentioned private and bank credit are the two important sources of short and medium term credit to U.K. agriculture.

emphasise an optimum stock level determined by economic forces. In particular it would seem that the relative prices of inputs, the rate of interest, the present level of stocks, and quality change of the input would be important at the aggregate level. The expected earnings effect may be important if farmers who demand tractors have similar expectations. Investment, considered by a time series study, may then be regarded as the means of adjusting past stock, either optimal or non-optimal, toward the optimal stock level in the present period under the economic forces operating to determine this optimal stock level. Complete adjustment may not be made within the time period; alternatively stock levels may be more than the economic optimum in each time period and more than complete adjustment occurs. Thus the adjustment process is affected also by technical variables and variables related to demand for tractors as a consumption good. Finally, adjustment is constrained by the relevant financial variables.

3. The Institutional and Technical Background

Before discussing the possible economic determinants of, and formulating farm investment functions for, new tractors, it is worthwhile to consider certain relevant aspects of the institutional and technical background as they affect such functions.

One such aspect is the question of whether or not a multiequation model is needed to explain the market in new tractors. This need may first arise because of the possibility of simultaneous determination of the price of new tractors. However, this possibility can be discounted, primarily because we are dealing with an oligopsonistic market where price is determined by a mark up over costs. This conclusion is supported by some discussion with the firms involved and by the existence of published list prices. The only possibility of simultanuous determination of price then arises through the practice of discounts given by dealers against the trade-in of old tractors. The relevant question is then whether or not this discount varies with the intensity of demand. Given the facts that (i) the region for discount is small;[1] (ii) there is recognised brand loyalty; and (iii) that the dealer's association publishes a guide to trade-in prices based on age and model of the trade-in, then the simultaneous problem does not seem so important. The existence of a substantial export trade in new tractors also means that manufacturers are not inclined to respond to demand pressures in the home market. A second possible source of simultaneous bias arises from the fact that a high % of total U.K. tractor production is exported. By number, the figure was 60% in 1948 rising to 80% in 1964(16). If there is interaction between home and export allocation, such that home demand may not be satisfied, then a model is needed that explains the total demand for U.K. production. However, although manufacturers tend to give some priority to the export market it seems that this simultaneity possibility can be discounted in this study. Firstly, annual data is used whereas the maximum lag between dealer order and delivery is one

1. Wholesale price is never less than 80% of list price. Further, dealers pay for tractors before delivery and also have to finance a fairly constant stock level.

month. Secondly, this lag is unlikely to affect sales to any extent because they are generally very low in December-January (the peak of sales occurs in March-April with a second peak in September). Thirdly, dealers generally order to restock rather than for a direct sale. However 1964 and 1965 were two abnormal years in that the two major manufacturers experienced production and hence supply difficulties. Even this apparent supply shortage may have been met by the large increase in imports for those two years and by increased sales from the smaller U.K. manufacturers. However the possibility of supply shortage in those two years is investigated by the use of a zero-one variable.

A second important aspect is that of quality change in the average tractor sold over the period. Aukrust(17) was one of the first to point out the importance of quality of the capital input in explaining production: from a cross sectional study of O.E.E.C. countries he found that important differences between countries were explained, not by the quantity of capital and labour employed, but by differneces in the state of technology. Griliches(18) has emphasised the need to take account of the changing quality of agricultural inputs; particularly when deflating expenditure series and measuring the services of capital equipment. He follows this up in his aggregate production function for U.S. agriculture(19) where he explicitly considered quality of the labour input, as measured by an educational variable, and found it to be a significant variable in the producton function. Even over the relatively short time period covered in this study (18 years) there has been quite significant changes in the quality of the average tractor sold. Quantitative factors include an increase in average horse power of tractors sold from 24h.p. in 1948 to approximately 50h.p. in 1965[1] and an increase in the proportion of diesel engined tractors[2] sold from less than 5% in 1948 to the total market by 1962.[1] Qualitative changes are related to incorporation of

1. See Appendix B (ii)
2. The chief quality variables of a diesel engine as opposed to a petrol or V.O. engine are fuel economy; use of a cheaper fuel and better performance at the same rated h.p.

hydraulics and p.t.o. systems into the standard models, sophistication of these systems(for example the features of independent p.t.o., automatic depth and draught control), the development of the differential lock, some form of gear change on the move and the provision of a much wider range of gears. I have constructed an index of quality change for tractors over the period based on a working principle as set out by Adelman and Griliches(20). The question to be asked in construction of this quality change index is "How much additional money would the average purchaser have to pay, compared to the base year, in order to get a basket of goods identical with the one he purchased in the base year except that the qualities available are those of the given year?" With the average of 1957-60 = 100 the constructed quality change index for new tractors sold increases from 42.5 in 1948 to 136.5 in 1965.[1] This then indicates that very significant changes in the quality[2] of the average tractor sold have taken place and will be important in the investment function. This is especially so as the demand for a durable input is really a derived demand - it is the services of the input that are used in production, not the input itself. This is provided that farmers in buying tractors do buy them on the principle of the services provided, rather than simply as a unit. The fact that the quality change index(and the quantitative measurements such as average horse-power) of the average tractor sold has shown a significant upward trend, when in any one year many models differing widely in quantitative and qualitative aspects are offered for sale,[3] indicates that tractors are bought for the services they provide. Hence it seems important to explicitly take account of quality change in the investment function. Here the studies of Cromarty(8) and Griliches(7) may be criticised in that they simply related numbers of tractors to economic variables with no variable for quality

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1. For a discussion of the procedure involved and the full index see the section on data selection.
2. In that quality is equivalent to utility for the purchaser.
3. The range of quality on offer obviously also moves in an upward direction as a lagged response to previous years' sales.

change[1] in the function. The same criticism may be levelled, to some extent, at other time series studies of the demand for durable inputs where a value measure is deflated by an index of the prices of manufacturing goods. This is to the extent that this price index is similar to the price index of the particular durable good and represents partly real price changes and partly price changes which c n be accounted for by quality changes. In this study I have tried to explicitly take account of quality change - by experimenting with three different dependent variables each considering quality change in different ways - as total services provided; as total horse-power provided; and as numbers arbitrily weighted by a light tractor versus heavy tractor distinction. Also I have tried using numbers as the dependent variable but with the quality index as an explanatory variable[2].

Three other 'background' aspects appear relevant to this study. Firstly, there has been government intervention in U.K. agriculture over the time period. It has been particularly important in keeping gross prices fairly stable, and further in giving farmers stable expectations as regards prices.[3] Hence farm incomes as a function of prices have been fairly stable also, variation has been due mainly to changes in the price of inputs and weather effects. Thus since farmers have been subjectively certain of the price and financial conditions affecting the profitability and ability to pay for durable assets, distributed lag models emphasising expectations[4] are not used in this study, Rather the possible influence of those variables which act as a 'proxy'for expectations is looked at in more general models.

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1. Griliches in fact deflated value of sales by an index of tractor price over the period. But since value = price x number this effectively reduces the value measurement to a number measure, since the price index was not adjusted for quality change.
2. These methods are further discussed under the selection of variables section.
3. Total guarentees cannot be reduced by more than 2½%/annum; individual prices by more than 4%/annum.
4. For example of the type set out by E.O. Heady and L.G. Tweeten, Resource Demand and Structure of the Agricultural Industry Ch. 10 pp. 278-281., Iowa State University Press, Ames, 1963.

Secondly, there has been quite a significant movement of labour out of agriculture[1] over the period while output has increased indicating capital substitution for labour. Thirdly, exports of used tractors from the U.K. increased rapidly from some 3000 in 1956 to over 10,000 by 1965.[2] This has caused variation in the average age of stock over the period, and the average loss rate from the U.K. stock. Further it is likely that it has raised prices in the second-hand market and encouraged replacement investment. Hence it may be an important factor in the adjustment process. Finally total expenditure on advertising new tracotrs is quite substantial. In view of the market structure then, this may simply have the effect of increasing or shifting brand loyalties. However it is also likely that advertising expenditure increases the replacement rate - in particular that it encourages replacement by a new model.

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1. For example, estimated input of hired labour (including casual, part-time) to U.K. agriculture was 651,000 year equivalents in 1948, 398,000 in 1964 (Departmental estimates)
2. See Appendix B.

4. Selction of the Investment Function

Single equation investment functions are used in the analysis: from the discussion in section three, simultaneous models, with respect either to tractor price or to an export/home allocation interrelationship, being considered unnecessary.

Following the theoretical standpoint of section two then the starting point for an investment function is a desired or optimal stock level. Thus farmers, particularly if profit maximisers(but also if utility maximisers with a profit constraint) desire a flow of services from an optimal stock of tractors. The economic forces operating to produce this desired stock S_t^* in period t are:-

(i) R_t, the relevant rate of interest in t

(ii) $\left(\frac{P_T}{P_I}\right)_t$, Price of tractors relative to other inputs.

(iii) Q_t, quality of the stock.

(iv) Expected earnings.

As proxy variables for expected earnings we can use lagged product prices $P_{C(t-1)}$ or lagged net real farm income Π_{t-1}, saying that expectations are based on the recent past forces affecting earnings. Lagged farm income is also the decision variable affecting the desired level of stock with respect to tractors regarded as consumer goods, providing utility to the user.

$$\text{Thus } S_t^* = f\left(\left(\frac{P_T}{P_I}\right)_t, R_t, Q_t, P_{C(t-1)}, \Pi_{t-1}\right) \qquad (1)$$

However we cannot assume that desired and actual stock will be the same and use (1) as the investment function. Stock in one period represents an adjustment from the previous period and adjustment to optimal stock may not be completed within one year. Firstly, the equilibrium is somewhat hazy, particularly since farmers cannot be sure how permanent the present level of the exogeneous variables is - although they may have some subjective impression. Secondly, the adjustment process is constrained by the other factors - technical and financial mentioned in section two. Thirdly, at the farm level tractors represent a discontinuous input; a marginal increase in the level of optimum stock may not generate any adjustment of actual stock. At the aggregate level this last point may not be important.

Annual purchases (gross investment) represent the adjustment made by farmers towards the desired level of stock. Gross investment during any one period(G_t) may then be thought of as the adjustment towards the desired stock level at the end of the period (S_t^*).

Thus $G_t = f\ (S_t^*)$ (2)

and we may substitute (1) into (2) to explain G_t.

Further G_t is constrained by the relevant technical and financial variables. Those not accounted for in explaining desired stock are lagged acreage per farm, change in the output mix, short term autumn weather influence and investment allowances. Also, since used exports represent a departure from normal scrappage and depreciation rates, and encourage replacement investment, then this must also be considered as an influence on G_t. Total advertising expenditure by tractor companies can similarly be viewed as encouraging replacement. Finally, we have a zero one variable for years of possible supply shortage. If we let all these factors be represented by Z then:-

$G_t = f(S_t^*\ Z)$ (3)

and we substitute (1) and the explanans of Z into (3) to explain G_t.

From (2) and (3) we obtain estimates of the short run influences of the variables on gross investment. For example if (2) was estimated by log-log regression we would obtain direct estimates, from the coefficients, of the short run elasticities of the variables on gross investment. However, because the adjustment process is not made explicit we cannot obtain estimates of (1).

Further no allowance is made for the influence of lagged stock on the adjustment process.

Gross investment represents an adjustment response to end of year stocks in the previous period (S_{t-1}) towards the desired level of stocks at the end of period t. Thus we can say that gross investment is some proportion g of the desired stock change, where g may have a value of more than unity because of the replacement demand generated by depreciation of S_{t-1}.

i.e. $G_t = g\,(S^*_t - S_{t-1})$ (4a)

If we substitute (1) for S^*_t and allow for the effects of the Z variables we have:

$$G_t = h\left[g\left(f\left(\left(\frac{P_T}{P_I}\right)_t, R_t, Q_t, P_{C(t-1)}, \Pi_{t-1}\right), S_{t-1}\right), Z\right] \qquad (5a)$$

where the coefficient of S_{t-1} has a negative sign if g is positive. From this we can estimate the short run response of G_t to the exogeneous variables and then, by dividing the coefficients by g, the long run response of desired stock to the economic variables. This function has the advantage of recognising that replacement investment can also be affected by economic forces as well as net investment.

The simple model (4a) of the adjustment process assumes that the response is proportional to the difference. In fact the adjustment might be a more complex procedure; one more sophisticated model which appears reasonable is that the response G_t will be proportional to the percentage disequilibrium. This has the advantage that the adjustment response is dependent upon the actual level of stocks (S_{t-1}) as well as on the disequilibrium - a more logical approach since replacement investment is also being considered.

i.e. $e^{G_t} = \left(\frac{S^*_t}{S_{t-1}}\right)^g$

or $G_t = g\,(\log_e S_t^* - \log_e S_{t-1})$ (4b)

Whereby the investment function is:-

$$G_t = h\left[g\left(f\left(\left(\frac{P_T}{P_I}\right)_t, R_t, Q_t, P_{C(t-1)}, \Pi_{t-1}\right), \log_e S_{t-1}\right), Z\right] \qquad (5b)$$

The functions (2), (3) and (5), are specific investment functions which have the advantage of using gross investment as the dependent variable, since gross investment is a more sensitive measure, than stocks, of investment behaviour. (5) also allows for the effect of economic forces on replacement investment and is explicitly trying to explain the adjustment process. Further it allows estimation of function (1), the desired stock equation. However, the coefficient g in (5) is not the adjustment coefficient of past stock to desired stock; it is simply a coefficient relating gross investment as a response to that stimulus. It seems important to estimate the adjustment coefficient as part of the investment study since it indicates how long the 'true' response to economic forces takes; that is how quickly the move towards desired stock is made. The simplest model is that assuming the adjustment is simply proportional to the disequilibrium. In this case however the adjustment relates to net investment, or stock change, and therefore the coefficient (g') lies between zero and unity.

i.e. $S_t - S_{t-1} = g'\,(S_t^* - S_{t-1})$ (6a)

therefore $S_t = g' S_t^* + (1-g')\,S_{t-1}$ (7a)

where S_t^* is determined by (1)

Griliches (op.cit. 7) proposed a more complicated stock adjustment model allowing direct estimation of the elasticities. Essentially this model assumes, more realistically, that the adjustment is dependent upon the actual, end of year stock in the previous period as well as on the disequilibrium. Thus the stock adjustment is a percentage increase, being some proportion g' of the percentage disequilibrium.

$$\text{i.e.} \quad \frac{S_t}{S_{t-1}} = \left(\frac{S_t^*}{S_{t-1}}\right)^{g'} \qquad (6b)$$

$$\text{therefore } \log_e S_t = g' \log_e S_t^* + (1-g') \log_e S_{t-1} \qquad (7b)$$

Since this study is primarily concerned with those short term influences affecting gross investment then the models (2), (3), (5a) and (5b) are of primary interest. Three alegebraic specifications were tried as being representative of models (2) and (3) and of the desired stock function (1). Specification of model(5) follows definition of the adjustment process and of function (1). The specifications used were

1) <u>Linear</u> which assumes that an absolute change in the exogeneous variable produces an absolute change in gross investment or desired stock.

It seems more realistic to assume that the change in gross investment or desired stock will also depend upon the level of the exogeneous variables.

Hence:-

2) <u>Logarithmic</u> which assumes that a percentage change in the exogeneous variables brings about a percentage change in the dependent variable.

3) <u>Semi-logarithmic</u> of the type $e^y = a_o x_1^{b_1} x_2^{b_2} \ldots e^u$ which assumes that a percentage change in the exogeneous variables brings about an absolute change in the dependent variable.

The coefficients of models (2) and (3) estimate the short run influence of the exogeneous variables on gross investment. Models (5a) and (5b), however, also investigate the long run effects of the economic variables on investment since the desired stock function (1) can be estimated by dividing the coefficients of these variables by g(the adjustment response of gross investment). Finally, models (7a) and (7b) primarily estimate the adjustment coefficient g' of actual stock to desired stock - this being an important facet of long run investment behaviour. Also it estimates the short run response of actual stock to the exogeneous variables; dividing these by g' gives a second estimate of the desired stock function (1) coefficients.

5. The Variables and the Data

(i) The Dependent Variable

A. Gross Investment

Gross investment per calendar year was expressed in four different ways. Firstly, by sales for each year in terms of numbers. Secondly, in terms of total available physical services - estimated by dividing value by the real[1] price (i.e. adjusted for quality change) of tractors in that year. Thirdly, by total horse power of sales. Fourthly, by numbers weighted as follows:-

i) Tractors $<$ 20 h.p. weighted by 0.5

ii) Tractors 20 h.p. - 40 h.p. weighted by 1.0

iii) Tractors 40 h.p. - 60 h.p. weighted by 1.5

iv) Tractors $>$ 60 h.p. weighted by 2.0

The boundary lines were not rigid but were used to try and distinguish the 'light' versus 'heavy' tractor.

The first measure implies that the purchaser does not recognise any quality differences between tractors - either between models within one year or comparing years. That is all tractors are identical as far as the provision of utility is concerned. Use of the second measure implies that purchasers recognise all the available qualities (as they provide services to be used in production) of the tractors and buy accordingly. The third measure implies that quality to the purchaser is equivalent to horse power; there is no consideration of the number of tractors providing the horse power and output is affected only by the total horse power. The hypothesis underlying the fourth measure is that purchasers primarily want a tractor unit but

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1. Derivation of the real price is described later.

extra utility is provided by tractors in the higher horse power groupings. Thus a tractor in the h.p. group (40 - 60 h.p.) has a higher potential work output than that in the 20 - 40 h.p. group but not to the extent suggested by the ratio of their horse-powers. (Average of 50 h.p. to average of 30 h.p. = 1.7 : 1). This is because for many jobs, and particularly in non-rush periods, the smaller tractor has the same work potential as the larger.

The four measures were used as being different hypotheses of the way in which farmers might have a demand for tractors. Conceptually the deflated value measure is the most rational since it estimates total available services to be used in production and also allows physical depreciation. However, better structural equations may be provided by the other measures if these are more appropriate to the way in which farmers buy tractors. If not they may still be important with regard to the prediction of future demand. It is also interesting to see whether the same or different variables affect the different dependent variables. For example if one variable affected demand for horse-power and not numbers, any change in this variable would affect the type of tractor bought. However, this sort of conclusion cannot be so easily obtained when the two dependent variables both take account of quality. Even if an exogeneous variable is significant in explaining, for example, demand in terms of horse power and not in terms of value, then because the two are interrelated, the variable still affects demand in terms of value.

Estimation of Gross Investment

There is no published data on the U.K. sales of new tractors; sales had therefore to be estimated. Two data sources were available : the Ministry of Transport series on new registration in the £3 : 15 : 0 class (A)[1] and

1. Letters in brackets refer to sources of data outlined in the Appendix A.

manufacturers shipments of new tractors (B) plus imports (C). The data on registrations is simply by total number; that on shipments by number broken down by model; that on imports by number and value. It was felt that the second set of data (shipments plus imports) was a better estimate of sales particularly since the model breakdown allowed easier conversion to the value, horse-power and weighted numbers measures. The figures on registration suffer from the further disadvantage that they underestimate sales and that the percentage error has probably altered over time. Also, in the years after the war until 1950 they overestimated sales because some old tractors were registered for the first time.

The figures on shipments were on a calendar year basis and are an accurate indicator of sales if end of year stocks do not change very much. This is likely since December-January are poor months for sales, dealers usually carry fairly constant stocks and tend to have a tractor shipped to them to replace one sold from stock. Further the lag between order to delivery is usually short; especially at the end of the year. Some upward bias in the other three measures of sales arises in years when new models are introduced - assuming that the new models are of improved quality. This is because even if dealers stock has not changed in number it will be of different quality at the end of the year of the old model to the end of year stock of the new model. However, this bias cannot be very large.

Sales by number of tractors was therefore estimated by adding imports of wheeled agricultural tractors to manufacturers' shipments of agricultural wheeled tractors, on a calendar year basis. The other three measures of gross investment were then estimated as follows:-

a) By Deflated Value

In each year, sales for each model were multiplied by the standard list price (D) for that model and aggregated to give total sales by value in current prices[1]. It is somewhat arbitrary to use list price but it was felt that this was best in view of two opposing influences on price. Firstly, discounting beneath list price is common; secondly, models are frequently sold with optional extras and thus at above list price.

The figures on values in current prices were then deflated by the estimated 'real' price of tractors. This removes all 'real' price changes from the series and gives estimates in terms of total available physical services only.

b) By Total Horse-Power

The only available horse-power rating covering every model over the whole period was belt horse-power. In each year sales for each model were therefore multiplied by listed belt horse-power (D) and aggregated.

c) By Weighted Numbers

In each year sales by model were appropriately weighted and aggregated.

The resulting series for gross investment are given in Table I:-

1. The value series in current prices is listed in the appendix.

TABLE I

Estimated Gross Investment Series

Year	Number	Deflated Value	Horse-Power	Weighted Numbers
	(rounded to nearest 10)	(£m) (rounded to nearest 100)	(in h.p. x 103) (rounded to nearest 100)	(rounded to nearest 10)
1947	43,990	10.8514	1,060.8	44,050
1948	43,110	11.1623	1,039.0	43,600
1949	34,820	10.1035	850.9	35,070
1950	35,870	10.7985	868.3	35,970
1951	33,540	11.4198	928.2	33,610
1952	35,560	14.7325	1,060.4	35,630
1953	36,430	14.3446	936.7	31,260
1954	37,430	19.0038	1,164.6	38,430
1955	41,230	21.3443	1,302.6	42,290
1956	30,020	14.7678	971.2	30,800
1957	41,060	22.9265	1,476.6	42,080
1958	46,600	28.3207	1,670.2	48,650
1959	50,630	31.8077	2,006.1	60,210
1960	43,330	27.8561	1,751.4	52,250
1961	44,420	30.2609	1,868.9	54,590
1962	41,030	28.4962	1,786.6	50,350
1963	45,820	33.5659	2,050.5	57,730
1964	42,060	32.3507	1,924.1	54,410
1965	41,660	34.6311	2,063.8	48,080

N.B. Crawler tractors were not considered in this study for several reasons. Firstly, they are a very specialised type of tractor and therefore probably fit into a separate demand pattern. Secondly, while they are only a small proportion of total sales of new tractors; data on them was difficult to obtain.

B. Stock of Tractors and Change in Stock (Net Investment)

These dependent variables were expressed in the same four ways as gross investment and for similar reasons.

Estimation of Stock

Estimation was concerned only with the stock of tractors which would affect future demand - that is those tractors regularly used for field work. Marks (21) has distinguished 2 fleets of tractors - the working fleet and the standby fleet. For this study the latter is defined as those tractors which are immobile and used for belt work only and those tractors which survive on farms but are rarely used. This definition is not the same as Mark's definition of the standby fleet which includes tractors used at peak times.

Estimation of Total Numbers

Ideally, estimates of total stock would be an end of year figure in view of calendar year figures used for the dependent variable. However, it is thought that the best estimate of stock is given by the September 30th licence figures[1] (A). The only two estimates of stock available at any time are these and M.A.F.F. census.[2] The former have the advantages that:

1) They are taken at the same time every year whereas M.A.F.F. census figures are not. Further the M.A.F.F. census figures were taken at different months in Scotland and N.I. to England and Wales.

2) M.A.F.F. census figures for the U.K. are only available for 6 years out of the 18 required.

3) It is thought that the licence figures correspond more closely to the working fleet number whereas M.A.F.F. census figures may include tractors which are not regularly used and the proportion of these may have changed over time.

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1. See Table (2) for the series.
2. Ministry of Agriculture, Fisheries and Food conduct a census every two to three years of the number of tractors on farms in the different countries of the U.K.

4) the M.A.F.F. census is taken on a sample and therefore is subject to sampling error.

5) The licence figure accounts for tractors worked by agricultural contractors; these are obviously important in affecting farm demand for tractors. Further the figures for shipments include tractors sold to agricultural contractors.

The major disadvantage of using licence figures is that not all farm tractors have to go on public highways and therefore need not be licenced. More important the % unlicensed may have changed over the period of study - and is almost certainly less now than in 1948. However, since the % unlicenced is estimated to be less than 5% (Motor - Business 1960; Talks with manufacturers) and almost certainly less than 3% when differentiating the working fleet, then the licence figure is likely to be more accurate. Further, errors of estimation on extrapolation of M.A.F.F. census figures are likely to be large in addition to the errors inherent in M.A.F.F. census figures. Although the disadvantages of using licence figures have been pointed out with regard to gross investment the % error involved with regard to stock is very much less.

Estimate of Total H.P.

Again an end of year figure would be ideal but since estimation had to be based on numbers from the licence figures then again an end of September figure for each year was obtained. Total h.p. of annual shipment of new tractors was known accurately from data obtained directly from all the manufacturers. However, the following estimates had to be made in order to estimate the total h.p. of stock:-

1) Number of tractors scrapped each year

This was assumed to be equal to:-

	Source
Total number from licence figure in year t - 1 (Sept. 30th figure)	(A)
+ shipments of new tractors in year t (calendar year)	(B)
- exports of used tractors in year t (" ")	(C)
- total licence figure in year t (Sept. 30th)	(A)

This may result in some bias in estimation if there is much year to year variation in autumn figures of shipments and exports of used tractors. However, since the % of tractors scrapped each year varies on average from 4-8%, in terms of total h.p. of stock, the bias will be small.

2) Export of used tractors (C)

The figure for calendar year was assumed to be the same as that for October to October shipments for the years in question. Some bias may arise if autumn shipments vary widely from year to year; but again numbers shipped as % of total stock are small - not more than 2% and therefore bias from autumn to autumn variation is likely to be small.

3) Average Age of Scrapped Tractors

This is assumed to be 9 years for every year considered. Marks supplies some evidence for this (21). Further, considering any years's total stock in number then the previous 8 years additions to stock plus shipment in that year (and allowing for exports of used tractors) is usually approximately equal to the total stock. That is total stock can be explained by tractors of not more than 9 years of age.

4) Average h.p. of scrapped tractors

For any year is assumed to be equal to the average h.p. of new tractors sold 9 years previously.

5) Average Age of Used Tractors That Are Exported

This is assumed to be 4-5 years of age. There is no evidence as to their age but this seems a rational estimate balancing depreciation of the tractor on one hand and age when traded in for a new tractor by U.K. figures on the other.

6) Average h.p. of Used Tractors for Export

For any year it is assumed to be equal to the average h.p. of new tractors sold 4 years previously.

Method of Estimating Total h.p. of Stock

Total h.p. of stock of tractors in 1946 was first of all estimated. The majority of these tractors were produced in the war years since, in 1939 there were only some 56,000 tractors on farms (A), by 1946 there were 148,590 tractors on farms (A). The increase was largely of Ford N. tractors - some 100,000 were shipped between 1939 and 1946. Hence the average h.p. was taken as being that of the Ford N. (22 h.p.) for the total stock as given by 1946 licence figures.[1]

The 1946 estimate was then taken as the base figure. Estimates for the subsequent years were made as follows:-

1. Estimate is 3,394,000 h.p. for 1946; cf Britton and Keith (A note on the Statistics of Farm Power Supplies in Gt. Britian) (Includes crawlers) 3,470,000 h.p. 1946. - Farm Economist - Vol. No. 6, 1950, page 167.

(i) To the estimate of h.p. of previous year stocks add on total h.p. of new shipments for present calendar year.

(ii) Estimate total h.p. of tractors scrapped in that year using assumptions (1), (3) and (4). Then subtract this estimate from the total of (I)

(iii) Estimate total h.p. of used tractors in that year using assumption (2), (5) and (6). Subtract this estimate from the total of (II).

This gives an estimate of total h.p. of working wheeled tractors on farms at the end of September in each year. (See Table 2). A source of bias arises because the total h.p. of new shipments is on a calendar year basis whereas estimates of stock are on an October to September basis. Hence if there is large year to year variation in autumn shipments then the estimate of total h.p. of stock will be biased. However, the bias is not likely to be very large - firstly as the peak of shipments is in the spring of the year, secondly total h.p. of new shipments is not more than 15% of total h.p. of stock. Possibly the largest source of error arises from the fact that scrappage rates are consistently overestimated every year. Thus change in total registration from year to year underestimates stock change, whilst additions to stock are measured by shipments of new tractors plus imports. Hence scrappage rates are too high. This error is not serious with regard to estimation of total stock because of the size of the latter but is with regard to scrappage rates. N.B. Autumn to autumn variation is not large, e.g. Autumn 1959 cf Autumn 1964 - 700 tractors difference whereas the total difference between the two calendar year figures is 8,000 tractors.

Estimate of Total Value

Again estimation was based on the total licence figure for the end of September. The estimates concerning numbers scrapped, numbers of used tractors exported and average age of scrapped tractors were made as before. A further estimate had to be made concerning depreciation rates. From data about discounts given for used tractors (from the Blue Book (E)) on trade in, depreciation rates were calculated on a diminishing balance formula - using the formula given by Mathieson (22) - of:-

$$\text{Rate of depreciation} = 1 - \sqrt[n]{\frac{S}{C}}$$

where C = original cost

S = present value

n = age of tractor

Mathieson recommends a depreciation rate of 22½%/annum. However, from the prices actually in use it appears the % rate varies with age of the tractor. Thus:-

Age	% Deprec. Rate
1 year	23% to 25%
2 year	19.2% to 19.7%
4 year	17%
5 year	14.3% to 15%
6 year	15%
7 year	15.5%
8 year	12.3% to 14.1%
10 year	13%
15 year	12%

Thus the depreciation rate used in the value of the whole tractor fleet will depend on the average age of the tractor population. Marks (21) puts this age at 5-6 years. Hence a depreciation rate of 15%/annum was used. This seems reasonable also in that a rate of 15% per annum is used, as indicated above, for depreciating tractors of between 5 to 7 years. Further it is an approximate rate to tractors of from 4 to 10 years, and the average age of the whole fllet can safely be assumed to lie within this range.

Method of Estimation

Total value of the stock of tractors at the end of September as given by annual licence figures was first of all estimated. Again since the majority of tractors in the stock were of Ford N type the average value of the stock could be assumed to be that of the Ford N tractor. Looking at shipments of the Ford N tractors during the war it was reasonable to assume that the average age of tractors in 1946 was 3-4 years. Hence the price of a new Ford tractor in 1943 was depreciated by the appropriate rate for 3 years to give an average value/tractor for the 1946 tractors. This was then multiplied by stock to give total value of stock.

Estimates of total value in subsequent years were then made as follows:-

i) Value of stock in previous year was depreciated by 15% - that is 15% of the value of the previous year's stock was subtracted from the value of that stock.

ii) (i) was then adjusted for scrappage of tractors in the present year. Thus if tractors are scrapped (i) underestimates the total depreciation - in that for our purpose scrappage includes those tractors withdrawn from the working fleet. The value attached in (i) to scrapped tractors was estimated as the % of tractors scrapped of total fleet in the previous year multiplied by the value attached to the previous year's stock of old tractors, (i.e. not including new shipments the previous year). Then since the scrapped tractors are assumed to have an average age of 9 years compared to the average age of the whole fleet of 5 years this figure was depreciated by 15% per annum for 4 years. The resulting value was subtracted from (i)

iii) The value of used tractor exports for the present year (c) was subtracted from (ii).

iv) Finally the value of shipments in the present years was added on to (iii) to give an estimate of total value of stock at end of present year.

The same sources of bias arise in the estimation of total value as that of total h.p. of stock. However, again, especially when considering the magnitude of total stock as against the likely variations in the autumn figures that can cause bias then this bias is not likely to be at all substantial. The value[1] series was then deflated by the estimated real price index of tractors to estimate stock in physical terms only. (See Table 2.)

Estimate of Stock in Terms of Weighted Numbers

This was calculated as follows:

i) Stock of tractors by number in 1946 was weighted 1.0

ii) New shipments for each year in terms of weighted numbers were added.

iii) The weighted number of scrapped tractors was subtracted (assuming the weight to be equal to average weight given to tractors sold 9 years previously).

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1. The value series in current prices is listed in the appendix.B.

iv) The weighted number of used tractors exported was subtracted (assuming the weight to be equal to the average weight given to tractors sold 4 years previously).

It is felt that the errors of estimation of this series are likely to be greater than for any other stock series because the discontinuous weighting system intensifies the errors. In particular there has been a trend in demand over the period toward the larger tractors. Because change in total registrations probably underestimates stock change then the % of new tractors in estimated stock is probably higher than it should be. This is particularly intensified by the weighting system and this error has increased from year to year. The series is givdn in Table 2.

<u>Estimation of Net Investment</u>

Net investment was simply calculated as the change in stock from year to year. It was measured in terms of number, deflated value and horse-power. Because it is a very sensitive measurement - very volatile and small in comparison with stock, - it was not calculated for weighted numbers in view of the probable errors involved in the calculation of stock by weighted number.

The estimated series for net investment are given in Table 3.

Table 2

Estimates of Stock Series

Year	Numbers	Deflated Value (£m)	Horse-Power (million)	Weighted Numbers
1947	194,000	29.32	4.454	194,000
1948	231,650	35.77	5.405	231,650
1949	269,910	41.19	6.256	269,910
1950	277,550	44.49	6.578	277,550
1951	285,810	48.55	6.950	285,810
1952	305,940	56.82	7.668	305,940
1953	327,720	64.82	8.474	328,550
1954	355,090	74.27	9.413	356,890
1955	365,750	81.56	10.033	368,830
1956	377,190	81.85	10.539	381,140
1957	394,860	92.39	11.796	399,880
1958	407,430	103.47	12.615	414,560
1959	423,370	119.13	13.735	440,310
1960	430,990	124.08	14.453	456,880
1961	437,570	130.14	15.427	473,650
1962	435,810	130.19	16.169	479,030
1963	444,320	139.84	17.008	496,150
1964	453,660	142.51	17.719	514,330
1965	451,000	143.43	18.315	535,080

Table 3

Estimated Net Investment

Year	Numbers	Deflated Value £m.	Horse Power H.P. 10^3
1948	+37,650	6.45	951.0
1949	+38,260	5.42	851.0
1950	+ 7,630	3.30	322.0
1951	+ 8,270	4.06	372.0
1952	+20,130	8.27	718.0
1953	+21,780	8.00	806.0
1954	+27,730	9.45	939.0
1955	+10,660	7.29	620.0
1956	+11,430	0.09	222.0
1957	+16,670	10.54	1241.0
1958	+12,570	11.08	1119.0
1959	+15,940	15.66	1120.0
1960	+ 7,620	4.95	718.0
1961	+ 6,590	6.06	974.0
1962	- 1,760	0.05	742.0
1963	+ 8,500	9.65	839.0
1964	+ 9,340	3.67	711.0
1965	- 2,660	0.92	596.0

N.B.

% scrappage rates were estimated as follows:

$$\% \text{ scrappage} = \frac{\text{scrappage (t)}}{\text{Total stock (Sept t - 1)}} \times 100$$

Year	%
1947	-
1948	2.0%
1949	-
1950	8.5%
1951	9.0%
1952	5.0%
1953	1.0%
1954	2.5%
1955	8.0%
1956	7.5%
1957	3.0%
1958	7.5%
1959	7.0%
1960	6.5%
1961	4.0%
1962	5.0%
1963	6.0%
1964	5.0%
1965	7.5%

As indicated these figures may overestimate scrappage particularly since 1950 - even under the definition of scrappage as withdrawal from the working fleet. They do, however, indicate some sort of cycle in scrappage with low points every 3 to 4 years.

(ii) The Explanatory Variables

A. Economic Variables

1) Tractor Prices and Quality Changes in Tractors

The use of different dependent variables, looking at the quality change over the period in different ways, meant that differing series on tractor prices were needed. Thus the price series used in each case should be relevant to the degree to which quality was accounted for.

Where the dependent variable is in terms of numbers, and with the hypothesis that all tractor units have the same utility to the purchaser, then any price change represents a real price change. This is because the purchaser is assumed not to recognise any quality change associated with the price increase. Hence the relevant price series in this case is that of the average price per tractor sold. However, although the purchaser buys simply in terms of tractor units, if there has been quality improvement in the units over the period, then productivity per tractor unit will have increased. Hence the marginal revenue curve from his stock of tractors will have been shifted upwards, even though he has not been buying tractors on their quality aspects. Thus we need a variable quantifying this quality change in purchases which we can call the quality change idex. As outlined by Griliches (23) and Griliches and Adelman (20) the quality change index of an item can be identified with those price changes associated solely with quality changes.

To estimate the dependent variable in terms of deflated value, taking account of all the qualities of the tractors sold, we need to estimate a real price series for tractors. Thus we have to distinguish between those price changes associated with quality changes and those that are real (not accompanied by any quality change). The real price series needed is thus on a constant quality basis. Having used this real price series to deflate value and estimate the total physical services available then the relevant price series in the regression is the same real price series. Thus because the dependent variable accounts for all quality aspects then the price series should not include changes in price arising from changes in quality.

Thirdly, when the dependent variable is measured in horse power then the hypothesis is that tractors are bought solely for horse power. Hence the relevant price variable is average price paid per unit of horse power sold.

The relevant price series to weighted numbers, used as the measure of the dependent variable is hard to define. The variable takes some account of quality variation but not to the extent that deflated value or total horse-power does. In fact it tends to follow numbers, rather than the two quality measures, in the trends in gross investment or stocks over the period. Hence average price paid per tractor unit was used as the relevant variable, although it does in fact overestimate the real price to the purchaser under the hypothesis concerning the weighted number dependent variable. The price of large tractors ($>$ 40 h.p.) relative to small tractors ($<$ 40h.p.) was also used in the regressions in conjunction with the average price paid. This was simply calculated on the basis of the average prices paid for each of the two types of tractors. This prtially allows for the fact that the dependent variable does take some account of quality.

The relevant price series were all calculated in index form and used in the regression relative to other prices - input and product prices. This meant that changes in the value of money did not have to be explicitly taken into account.

Estimation of the Tractor Price Series and the Quality Change Index

1) Average Price per Tractor in Current Prices

This was estimated by dividing estimated total value of sales each year (in current prices) by total number of tractors sold. The resulting prices then put into index form with 1957-60 = 100.

2) The Constant Quality Price Index for Tractors

Calculation of a constant quality price index for tractors was a project in its own right and only a summary of the procedure is given here.[1] The method used has been partially outlined by Griliches (23) and partially used by Fettig(24) and consists of three stages. First, adjust for quality changes to which a price can be attached. Then, derive implicit specification prices from cross sectional data on the price of various models. Thirdly, use these specification prices to calculate a price time series using representative specifications.

The study[2] looked at tractor models each year from 1948 to 1965 using

1. For a fuller discussion see a forthcoming report from the Dept. of Agricultural Economics, Manchester University.
2. Data sources for this study:- (D) (F) and (G) in the appendix A.

only those models without special features (i.e. excluding crawlers, and high clearance models). The list prices of those models within and between years then varies partly because of quantitative attributes, for example horsepower, and partly because of qualitative aspects, such as attachments to the model. The prices of models were then first adjusted for qualitative attachments, so that all models were put on the same basis. This basis was a tractor equipped with simple hydraulics, p.t.o. and self starter. The prices attached to the qualitative aspects were estimated from their costs when they were given as optional extras to the standard model. Thus, if the standard list price was inclusive of a pulley, then the value attached to the pulley was subtracted from the list price. Similarly if the hydraulic or p.t.o. system was more sophisticated than when first introduced - if for example it included independent p.t.o. - then the value attached to the extra quality was removed from list price. Alternatively, where list price did not include hydraulics then the cost of hydraulics as an extra was added onto list price. This 'stripping' technique should not result in any bias - unless there are economies of producing attachments or improvements as part of a standard model rather than as extras to the standard model.

The assumption is then made, that for any one year, differences between the adjusted prices of models is because of differences in their quantitative specifications. Thus all other specifications have been held constant by adjusting the prices to represent the defined basic unit. Cross-section regression for each year can then be carried out using the models as the units of observation and making price a function of the quantitative specifications.

It was found that only two variables were significant in explaining cross section variation in prices : belt horse-power and a dummy variable with value zero if the tractor had a diesel engine, one if it was equipped with a petrol or V.O. engine. Maximum pounds pull, drawbar horse power and weight were highly correlated with belt-horse-power; similarly fuel economy was highly correlated with engine type and these other variables added nothing to the explanation of price variablility. Similarly distinguishing between a V.O. and petrol engine contributed nothing. A semilog regression provided the best fit out of various regression forms used and the results are given in Table 1 (the dependent variable was in log form; the explanatory variables in natural form).

The third step was to find representative specifications in terms of horse-power and engine-type for the whole period. Then substitute these into the regression equations, generate a price for each year and use these prices to form an index. The prices would then all be on a constant quality basis. The representative specifications chosen were those of the average of sales 1957 -60. (Average h.p. = 38.8, average % of total sales of V.O. and petrol engines = 2.7%). They were chosen from these years because the majority of model changes, particularly with regard to horse-power, have occurred in the last ten years. Thus specifications representative of the centre of the whole period would give too much bias to the early part of the period. The constructed index again had the base 1957-60 = 100 and is given in Table 2.

Table I

Cross Section Regression Equations Explaining Tractor Price (in log form) as a function of Horse power and Engine-type

Year	Constant	Coefficient of		$\bar{R}^2$
		Horsepower	Petrol V.O.	
1948	5.705	+ 0.02657	– 0.2543	0.58
1949	5.646	+ 0.02824	– 0.3380	0.85
1950	5.512	+ 0.03133	– 0.2682	0.77
1951	5.871	+ 0.02127	– 0.2662	0.53
1952	5.862	+ 0.01954	– 0.1980	0.65
1953	5.809	+ 0.01969	– 0.1873	0.72
1954	5.835	+ 0.01854	– 0.1746	0.67
1955	5.722	+ 0.02141	– 0.2000	0.66
1956	5.819	+ 0.01853	– 0.1511	0.75
1957	5.719	+ 0.02050	– 0.1313	0.75
1958	5.808	+ 0.01808	– 0.1057	0.79
1959	6.030	+ 0.01121	– 0.0977	0.72
1960	6.039	+ 0.01102	– 0.1380	0.80
1961	6.035	+ 0.01108	– 0.1302	0.79
1962	6.096	+ 0.01033	– 0. 1436	0.85
1963	6.002	+ 0.01229	*	0.77
1964	5.907	+ 0.01535	*	0.85
1965	5.972	+ 0.01479	*	0.88

* coefficient non-significant.

3) The Quality Change Index

The construction of the quality change index is based on the working principle set out by Adelman and Griliches (20)[1]. It is based on the assumption that quality change only concerns those qualities for which a price is being paid or extracted and only to the extent of the price differential. This seems fairly reasonable where the purchaser has the choice of many varieties of the same good in any one year - as in this case.

Griliches (23) shows that the true or real price index of an item is obtained by deflating the observed price index by the quality change index.

$$\text{Hence: Quality Change Index} = \frac{\text{Observed Price Index}}{\text{Real or True Price Index}}$$

That is, by taking out those price changes which are real, from the observed price changes, we are left with price changes which can be accounted for solely by quality changes. This corresponds to the Adelman - Griliches principle.

Thus the quality change index was simply estimated from the two calculated price indices. (See Table 2).

4) Average Price/H.P.

This was calculated by dividing estimated total value of sales for each year by estimated total horse power of sales. The generated price serids was then put into index form with 1957-60 = 100. (See Table 2)

5) Average Price of Large Tractors/Average Price of Small Tractors

The average price for each of the two groups was first calcualted by dividing estimated value of sales for each group by number of sales relevant to each group, for each year. The estimated price of large tractors was then divided by the estimated price of small tractors in each year and an index constructed with 1957-60 = 100. (See Table 2)

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1. This principle has already been defined - in the section on Technical and Institution Background to the analysis.

Table 2

Generated Price and Quality Change Series

Year	Average Price per Tractor	'Real' Price (Constant Quality) per Tractor	Quality Change Index	Average Price per H.P.	Price of Large Tractors ÷ Price of Small Tractors
1948	53.5	126.0	42.5	80.2	238.0
1949	58.7	123.2	47.7	84.3	218.0
1950	60.7	122.8	49.4	91.0	200.0
1951	67.6	121.0	55.9	95.0	185.0
1952	78.6	115.5	68.1	92.7	162.8
1953	84.0	108.4	77.5	99.9	116.3
1954	88.8	106.5	83.4	103.3	106.4
1955	89.0	106.1	83.9	108.2	98.7
1956	84.6	104.8	80.7	106.8	104.3
1957	94.0	102.4	91.8	99.2	97.1
1958	101.8	102.0	99.8	107.7	103.4
1959	101.0	97.9	103.2	96.6	100.7
1960	103.3	97.9	105.5	96.9	99.6
1961	109.3	97.7	111.9	98.4	103.6
1962	115.0	100.9	114.0	100.1	103.5
1963	119.6	99.4	120.3	101.2	103.6
1964	128.3	101.6	126.3	106.3	107.2
1965	145.0	106.2	136.5	110.9	118.8

All in Index form: 1957-60 = 100

2) Prices of Other Inputs

Tractors are a basic input to farm production because of their role in supplying draught power. This is particularly so, in that horses, were only important in the early part of the period under study.[1] Thus, there were no close substitutes for tractors over the period. There was, however, some substitutability with labour, especially if we consider tractors in quality terms and labour in total earnings terms. Thus for example, tractor quality can substitute for labour overtime; if the price ratio between the two decreases further, this tractor quality or even tractor units may substitute for part of the total labour force. That this may be important in explaining tractor demand has been emphasised by the drift of labour from agriculture over the past 20 years whilst total production has increased. Hence labour wage earnings (H) were put into index form (1957-60 = 100) and then used in the regression in the form tractor prices relative to labour earnings (index form 1957-60 = 100).[2] Because the wage series was a June - May sereis then tractor prices in (t) were put on a relative basis to wage earnings June (t-1) to May (t).

Complementary inputs to tractors include fuel and some types of farm machinery. It was felt that changes in the price of these inputs were unlikely to have much effect on tractor demand and hence they were not used in the regression.

3) Rate of Interest

As emphasised, the chief source of external credit to farmers is the banking system, hence the relevant interest rate is the one charged by banks to farmers. There is no definite evidence on interest rates paid by farmers,

1. Even in 1947 horses supplied only 10% of the total draught power on farms (in terms of total horse-power).
2. The relevant series are set out in Appendix B.

therefore, the question is whether they are charged a fixed amount above bank rate or whether it varies with the level of bank rate (in which case bank rate itself is a sufficient measure of the movement of interest rates). Discussion seemed to indicate that farmers were charged 1% above bank rate at all times, however both bank rate plus 1% and bank rate itself were tried in regressions.

Bank rate for the calendar year was calculated as the weighted average of the level of bank rate; weights being the % of the year the rate was in force (source (I)).[1]

4) Expected Earnings

The two variables used as proxy for expected earnings were lagged crop prices and lagged 'real' farm income. The latter is also the relevant variable with regard to the demand for tractors as part of a utility function of profit and leisure. It is further one of the financial constraints imposed upon the investment decision.

U.K. net farm income (J) on a june to May basis was deflated by an index of the prices of manufactured products to give 'real' farm income. Two variants of lagged farm income were tried.[2] Firstly a simple lag using the deflated income, in the period, June (t-1) to May (t). Secondly a weighted average of past farm incomes giving June (t-1) - May (t) a weight of 3, June (t-2) - May (t-1) a weight of 2 and June (t-3) - May (t-2) a weight of 1. This second variable for lagged farm income allows that expectations of future earnings are not based solely on the most recent experience of earnings; also that ability to pay for a tractor may depend on the level of profit over several years.

1. The series is given in Appendix B.
2. The series is given in Appendix B.

Lagged crop prices, rather than total product prices, were used as the alternative expectation variable on the basis that the demand for tractors is mainly related to cropping as opposed to livestock production. A crop prices index (1957-60 = 100) on a calendar year basis, was used in the regressions in the form tractorsprices in (t) relative to crop prices in (t-1). This form was used to estimate the 'realness' of crop prices with respect to future earnings: if both tractor prices and crop prices are likely to rise then future earnings may not increase. Although there are two Ministry of Agriculture published price indices (L,M) each covering part of the period they cannot be put into one index by putting both on the same base. Firstly, one uses a chain linked weighting system, the second, a fixed weighting system for calculation of the farm crop index. Further, because one is for England and Wales and the other for the U.K. the indices for any individual crop cannot be converted to one common index. Hence an index had to be calculated, first by calculating separate indices for individual crops, based on gross prices received, for the whole period; then weighting these to give an index for farm crops as a whole. The weights used are those givenfor the U.K. farm crop index 1954-7 =100 (M) and for the crops considered are:-

Wheat	Barley	Oats	Maincrop Potatoes	Sugar Beet
56	41	9	48	22

The index was put on a 1957-60 = 100 base and is:-

Year		Year	
1947	69.9	1956	100.5
1948	78.5	1957	93.8
1949	77.7	1958	113.9
1950	82.3	1959	103.3
1951	97.6	1960	90.0
1952	92.8	1961	90.9
1953	92.8	1962	102.4
1954	90.9	1963	101.1
1955	95.7	1964	92.2

The series for tractor prices relative to this index is given in Appendix B.

B. Technical Variables

1) Farm Acreage

There is no published data on average farm acreage; the variable chosen to represent this was the % of farms in the U.K. of more than 300 acres (calculated from data published in (M).[1] The variable was lagged one year.

2) Change in the Output Mix

Because production is very sensitive to the weather, it was felt that planned output in the form of acreage was a better variable than the actual output mix. Hence the total tillage acreage was used as a proxy for planned changes in the output mix. A three year weighted average with weights of 3 given to acreage in June (t-1), 2 to acreage in June (t-2) and 1 to acreage in June (t-3) was used (data source(M)). The three year weighted average should

1. The series is given in Appendix B.

be more representative of a permanent change in planned output mix; crop acreage in any one year may deviate from planned because of the weather influence.

3) The Autumn Weather Index

With reference to the effects of autumn weather on the following spring demand for tractors, the months of September, October, November and December in year t-1 were considered. It was thought that the particular weather influence that was important, was that of rainfall affecting the number of available working days. The relevant data available (N) consisted of rainfall data in terms of:-

1) % deviation from normal for rainfall for each month with respect to different areas of the country.

2) The deviation from normal in terms of the number of raindays[1]; again with respect to areas and months.

Three simple alternative indices were constructed as follows:-

1) This was based on the premise that it is total rainfall in the autumn which constrains the quantity of tractor work performed that autumn and therefore affects the demand for tractors the following spring. Five of the meteorological regions were considered as the most important with regard to variability in tractor demand. These are the arable/mixed farming areas:-

1) E. Scotland; 2) N.E. England; 3) E. England; 4) Midlands; 5) S.E. England.

Each month was assumed to be important in relation to the amount of work that is normally performed in that month. This was based on the Cambridge scale (O) for number of work days per month (this seemed fairly appropriate in view of the regions considered):-

1) September 22 days 2) October 19 days 3) November 16 days 4) December 15 days

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1. A rainday is a day on which >0.1" of rain falls.

The rainfall index was thus constructed, first by finding the weighted average of the % deviation from normal by month according to the work days scale, for each region. This gave the weighted average % deviation from normal for the autumn for each region. Regions were then weighted on the basis of the cultivated acreage within each region and a weighted average obtained. This last weighted averagd was then used as the rainfall index.

2) This index was based on the premise that it is the deviation from average in terms of raindays that constrains the available autumn tractor working time. A weighted average by month and region for raindays was constructed using the same weighting as in the rainfall index.

3) This index was based on the same premise that it is the number of raindays rather than the amount of rainfall which is the important factor. However, in this case the assumption was made that a rainday was wquivalent to the loss of one available working day. Hence the monthly deviation in raindays was added or subtracted to the respective monthly figures of available working days. The figures for each month were then added and finally a weighted average for the five regions was calculated. This was then an estimate of the number of available autumn working days.

The three alternative series are given in Table 3.

Table 3

Constructed Autumn Weather Indices

Year	Rainfall: weighted average % Deviation from normal	Raindays: weighted average % Deviation from normal	[1]Estimated number of available autumn working days
1947	59.3	-3.9	87.6
1948	81.9	-3.0	84.4
1949	79.7	-1.9	78.5
1950	115.9	+1.3	68.0
1951	111.1	-1.9	78.6
1952	119.3	+1.7	67.3
1953	74.7	-3.7	89.1
1954	114.4	+2.4	63.6
1955	85.3	-2.7	82.5
1956	82.0	-2.2	81.6
1957	105.1	-1.7	80.6
1958	106.3	-0.1	72.8
1959	85.3	-1.9	75.6
1960	170.4	+5.2	50.6
1961	110.7	+6.1	72.6
1962	91.9	-1.5	78.9
1963	84.8	-0.9	75.4
1964	60.5	-3.1	88.6

1. Normal number of available working days for the period is 72.

C) Institutional Variables

1. Used Exports

This variable was defined on a calendar year basis and was obtained by number and value from (C). Used exports in terms of h.p. were estimated as described in the derivation of stock of tractors by h.p.

2. Advertising Expenditure

This was defined as total recorded press advertising expenditure on motor tractors, U.K. and Eire (P). £m in t.

D) Financial Variables

1. % Investment Allowances

Data source (D). The rate has usually been changed in March or November; the rate pertaining over the greater part of the calendar year was used for year t.

2. The Lagged Profits and The Interest Rate variables have already been described and defined.

E) Dummy Variable for Supply Shortage

It was indicated by talks with the manufacturers, and by looking at the changes in the level of imports of new tractors that 1948, 1964 and 1965 were years of major supply difficulties with respect to the home market. A variable given one for these years and zero for all other years was used in the initial regression analysis to see if this shortage was significant in restricting demand. If so this would pick up the level of the demand restriction.

6) The Results

Introduction

Analysis was by traditional multiple least square regression, minimising the sum of the squared deviations from the estimated regression equation. A positive model, rather than a normative model,[1] was used since analysis was concerned with estimating the actual demand relationship as it existed over the period. Time series data, rather than cross section data, was used because the objective of the study was to analyse the influences on investment at the industry level, rather than the firm level. Thus, aggregation over firms may mean that some influences, important at the firm level, become unimportant at the industry level.

The number of variables, that could be used in any one regression, was constrained by the potentially low number of degrees of freedom resulting from the use of only eighteen annual observations. However only annual data was available, also supply shortages may be more important over a shorter data period. Hence more complex models would have been required if quarterly data had been used. Prewar data was not used since it would have been unrealistic to include it in the same demand function. Data of the immediate post war years was not used, because of the possible distorting effects of the release of war time 'pent up' demand. Variables were tested for significance at the 5% level by the F test. A rough guide to significance at the 5% level, with the number of degrees of freedom available from the regressions, is that a coefficient can be called significant if it is more than or equal to twice its own standard error. The residuals of the regression equation were tested for autocorrelation by the von Neuman ratio; again

1. For example, a demand relationship could be estimated using integer programming with variable tractor prices maximising a net farm profit objective function subject to a budget constant.

with the degrees of freedom available a rough rule is that there is positive autocorrelation when the statistic is about 1.0; negative when it is about 3.0. (The inconclusive range is 1.0 to 1.5 for positive autocorrelation; 2.5 to 3.0 for negative autocorrelation.)

The definition of many regression equations, and the significance of variables in the regression, was hampered by the existence of a high degree of collinearity between many of the possible explanatory variables. Thus, for example, the weighted lagged crop acreage was highly correlated with the majority of possible explanatory variables; its introduction into an equation merely resulted in a reduction of the significance of other variables. Further it was itself non significant. Because this variable did not add anything to the explanation of the regression equations it entered,[1] it was concluded that it was not important and could be left out of the regression. However, other explanatory varaibles which appeared to have some importance - because they added to the 'fit' of the regression - may have appeared non-significant because of their high degree of simple (zero order) correlation with other explanatory variables.

The zero order correlation matrix does in fact indicate that many explanatory variables were highly correlated with each other. The interest rate variables suffered particularly badly from this statistical handicap. They had high[2] zero order correlation coefficients with all the lagged stock variables; with the two price varaibles $\frac{P_{T(t)}}{P_{L(t-1)}}$[3] ; $\frac{P_{T(t)}}{P_{C(t-1)}}$[4] where the tractor prices were real;

1. By comparing the $\bar{R}^2$ of similar equations with and without the variable.
2. In the order of $r^2 = \pm 0.8$ to 0.9.
3. Price of tractors in t relative to the price of labour in t-1 (year ends June (t)).
4. Price of tractors in t relative to the price of crops in t-1.

with the ratio of the average price of tractors to the price of crops (t-1) and with the price of tractors per h.p. relative to the price of labour (t-1). They were also highly correlated with advertising expenditure and the crop acreage variable. The important intercorrelation are indicated in array I.

The very high intercorrelations of lagged stocks, by h.p. and deflated value, with the relevant ratio of price of tractors to price of labour is important with regard to evaluation of the regression equations. This is particularly so in comparing gross investment equations with and without the lagged stock variable. Advertising expenditure, like interest rate, is highly correlated with many other variables and there is difficulty in introducing it into equations, particularly those that include lagged stocks. The two price ratios are not highly correlated with each other - except where the tractor price is in real terms. In particular, the average price of tractors relative to the price of labour and the price per tractor h.p. relative to the price of crops have low zero order correlation coefficients with other relevant explanatory variables: they could be evaluated in the usual manner. Similarly, real net farm income (both with simple and weighted lags) has low intercorrelations and there was no difficulty in evaluation of the attached coefficients.

However, where variables that were highly intercorrelatedwere used in the regression equations the coefficients may not have been very precisely estimated. Further, because of this problem they may have appeared non significant even though their influence was important. However, where the overall fit of the equation was high then this indeterminateness problem could be ignored to some extent. But, regression equationsincluding interest rate or advertising expenditure were especially prone to the problem: because of the wide range of high intercorrelations of these variables

TABLE OF THE IMPORTANT ZERO-ORDER CORRELATION COEFFICIENTS

(signs indicate direction of the simple correlations)

	$R_t + 1\%$	Average $\frac{P_{T(t)}}{P_{c(t-1)}}$	$\frac{P^R_{T(t)}}{P_{c(t-1)}}$	$\frac{P^R_{T(t)}}{P_{L(t-1)}}$	$\frac{P^{HP}_{T(t)}}{P_{L(t-1)}}$	$S^{(N)}_{t-1}$	$S^{(V)}_{t-1}$	$S^{(HP)}_{t-1}$	I_t	V_t
$R_t + 1\%$	1	0.74 +	0.77 −	0.87 −	0.83 −	0.78 +	0.80 +	0.79 +	low	0.78 +
Average $\frac{P_{T(t)}}{P_{c(t-1)}}$		1	*	*	*	0.82 +	*	*	0.77 +	0.93 +
$\frac{P^R_{T(t)}}{P_{c(t-1)}}$			1	0.90 +	*	*	0.75 −	*	low	low
$\frac{P^R_{T(t)}}{P_{L(t-1)}}$				1.	*	*	0.95 −	*	0.73 −	0.91 −
$\frac{P^{HP}_{T(t)}}{P_{L(t-1)}}$					1	*	*	0.97 −	0.76 −	0.94 −
$S^{(N)}_{(t-1)}$						1	*	*	0.75 +	0.93 +
$S^{(V)}_{(t-1)}$							1	*	0.82 +	0.98 +
$S^{(HP)}_{(t-1)}$								1	0.83 +	0.98 +
I_t									1	0.83 +

$R_t + 1\%$ = weighted average of bank rate in (t) + 1%.

Average $\frac{P_{T(t)}}{P_{c(t-1)}}$ = average price of tractors (t)/price of crops (t-1).

$P^R_{c(t-1)}$ = real price of tractors (t)/price of crops (t-1).

$\frac{P^R_{T(t)}}{P_{L(t-1)}}$ = real price of tractors (t)/labour earnings (t-1).

$\frac{P^{HP}_{T(t)}}{P_{L(t-1)}}$ = price per tractor h.p.(t)/labour earnings (t-1).

$S_{t-1}(N)$ = lagged stock by numbers (t-1).

$S_{t-1}(V)$ = lagged stock by deflated value (t-1).

$S_{(t-1)}(HP)$ = lagged stock by total h.p. (t-1).

I_t = % investment allowance in t.

V_t = total press advertising expenditure on tractors in t.

N.B. * These correlation coefficients are irrelevant to the regression formulae.

and need careful interpretation. Similarly, regression equations without these variables but including two other highly intercorrelated variables need careful interpretation.

2. Summary of the Regression Equations

Because of the complexities involved by having the dependent variable expressed in four different ways, it seems worthwhile to first discuss those variables which had no influence in any of the regressions. We may then consider only the useful variables, with respect to the different model formulations. The decision, as to which variables could be ignored, was taken only by testing variables in the gross investment functions (but trying each of the four ways of measuring the dependent variable). The variables, which were always non-significant and always added nothing to the 'fit' of the regression equations, were the dummy supply variable and the weather indices. Lagged total crop acreage, lagged net real farm income and used exports were also eliminated as being unimportant because they were again always non-significant, though they did sometimes add to the total explanatory power of the regression equations.

The dummy supply variable always had a coefficient of a size less than its standard error, although of the expected sign (positive). Similarly, the weather variables had coefficients less than their standard errors and frequently had the opposite sign to that expected.

Lagged total crop acreage was highly correlated with many other variables and reduced the usefulness of the regressions it entered. Further, it was often negative when it was expected to be positive. Lagged[1] net farm income usually had a fairly high coefficient in relation to its standard error but was never significant

1. The same results applied to the simple and weighted lag.

at the 5% level. Therefore it is concluded that it has no influence on gross investment in tractors.[1] However, it always had a negative coefficient of a fairly stable size. The simple lagged net farm income tended to have a higher F value than the weighted lagged variable but the F value fluctuated from 0.7 to 2.3, in the differing regression formulae.[2] The used exports variable similarly had a fairly high F value but was non-significant at the 5% level. It did however have the expected positive sign.

The question of which interest rate variable to use also resolved by experimentation with different gross investment functions. In fact, both variables behaved very similarly but the interest rate plus surcharge of 1% was usually slightly more significant or less non-significant depending on the regression formula. This was therefore used in the final models. It is interesting to note that interest rate +1% usually performed best when it entered a linear regression equation rather than a logarithmic or semilogarithmic equation. In contrast, the majority of other variables were more significant in a semilogarithmic regression[3] than in a linear or log - log regression. The semilogarithmic form for the gross investment function also had a higher $\bar{R}^2$ than a similar log - log form; though there was little difference between it and the linear form with regard to the goodness of fit. These points are illustrated to some extent by three regression equations with gross investment in terms of h.p. to 10^3 :

$$1)\quad G_t = \underset{(6.2)^*}{36.4} - \underset{(0.03)}{0.15}\frac{P_{T(t)}}{P_{L(t-1)}} - \underset{(0.42)}{0.80}\,(R_t + 1\%) + \underset{(0.048)}{0.047}\ \%\ \text{investment allowance}$$

$$\bar{R}^2 = 0.91$$

---

1. This is particularly so as it was not highly intercorrelated with any other explanatory variables.
2. The F value was highest in those regressions where the dependent variable was in terms of h.p. or value.
3. With the dependent variable in its natural form.
* The figures in parentheses indicate the standard errors of the associated coefficients.

2) $$G_t = \underset{(16.8)}{98.9} - \underset{(2.9)}{17.0} \log_e \frac{P_{T(t)}}{P_{L(t-1)}} - \underset{(1.9)}{2.4} \log_e (R_t + 1\%) + \underset{(0.025)}{0.033} \log_e \% \text{ investment allowance}$$

$$\bar{R}^2 = 0.91$$

3) $$\log_e G_t = \underset{(1.3)}{7.9} - \underset{(0.23)}{1.09} \log_e \frac{P_{T(t)}}{P_{L(t-1)}} - \underset{(0.15)}{0.06} \log_e (R_t + 1\%) + \underset{(0.026)}{0.032} \log_e \% \text{ investment allowance}$$

$$\bar{R}^2 = 0.89$$

Thus the semilogarithmic form was generally used for gross investment functions but where it seemed likely that the rate of interest was an important variable a linear formulation was used.

The more useful regression equation are presented below. No equations corresponding to the model (4_a)[1], developed in section (4), are presented because lagged stock, entered in a linear form, was never significant and never added to the explanatory power of the equations it entered.

A. Results with the Dependent Variable Measured in Number of Tractor Units

The price ratios used with this dependent variable refer to the average price of tractors; lagged stock refers to lagged stock by numbers.

1. Gross Investment

Table I summarises the more useful results with gross investment measured as thousands of tractor units. None of the regression equations were very satisfactory. There is a poor fit (only 33% of the variation in gross investment is explained) and the coefficients are non-significant at the 5% level except for log $\frac{P_{T(t)}}{P_{L(t-1)}}$ in equation (3).

However, both variables in equation (1) are significant at the 10% level;

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1. $G_t = g\,(S_t{}^* - S_{t-1})$.

although the actual size of the coefficient estimates may not be valid it does appear that both the cost ratio of tractors to labour and the quality change index are important influences on the level of gross investment. Adding the % investment allowance variable by equation (2) adds to the overall explanation of G_t but increases the non-significance of the coefficients, particularly that of the quality change variable.

Equations (3) and (4) relate to the more comprehensive gross investment model[1] developed in section (4) making gross investment the response to the stimulus of a disequilibrium between desired stock at the end of t and the end of year stock in (t-1). The equations offer no evidence to support this hypothesis; lagged stock being non-significant. However, equation (3) increases the fit compared to equation (1) and $\log_e \frac{P_{T(t)}}{P_{L(t-1)}}$ becomes significant at the 5% level. The partial elasticity of gross investment, by number, to the ratio of the price indexes of average price of tractors to the price of labour in (t-1) is estimated[2] from this equation as -0.95, at the mean level of G_t ($39.92 \cdot 10^3$). Thus, all other factors remaining constant, a 10% fall in average tractor prices (or a 10% rise in labour earnings) would result in a 9.5% increase in sales of new tractors from the mean level of sales. This is the estimate of the point elasticity of demand at the mean of gross investment. Alternatively from the coefficient of

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1. $G_t = g(\log S_t^* - \log S_{t-1})$

2. In a semilogarithmic function, the elasticity is calculated by dividing the coefficient by the level of the dependent variable. Usually this latter is at the mean. Thus for example if the function is of the type:-

$$e^G = a_o X_1^{b_1}$$

$$\text{Then } \frac{dG}{dX_1} = \frac{b_1}{X_1}$$

therefore elasticity of G with respect to $X_1 = \frac{b_1}{X_1} \cdot \frac{X_1}{G} = \frac{b_1}{G}$

TABLE 1. Regression Equations Explaining Gross Investment by Numbers

Equation	Definition of the Dependent Variable	Constant	$\text{Log}_e \frac{P_{T(t)}}{P_{L(t-1)}}$	$\text{Log}_e Q_t$	$\text{Log}_e I_t$	$\text{Log}_e S_{t-1}$	$\bar{R}^2$	d* *
(1)	Gross investment in t by numbers (10^3)	164.0 (88.2)*	-32.15 (17.49)	6.00 (3.42)			0.31	2.09
(2)	Gross investment in t by numbers (10^3)	166.9 (86.9)	-29.25 (17.40)	1.825 (4.830)	1.257 (1.042)		0.33	1.82
(3)	Gross investment in t by numbers (10^3)	204.3 (95.4)	-37.95 (18.21)	20.87 (14.21)		-22.29 (20.68)	0.32	2.06
(4)	Gross investment in t by numbers (10^3)	199.7 (95.4)	-34.42 (18.52)	14.65 (15.46)	1.090 (1.070)	-18.38 (21.02)	0.32	1.79

$\frac{P_{T(t)}}{P_{L(t-1)}}$ = index of average price of tractors (t)/index of labour earnings (t-1)

Q_t = quality change index in t

I_t = % investment allowance (given 1% in years when no allowance; in other years 1% added to the % allowance).

S_{t-1} = stock by numbers in (t-1) in 10^4

* The figure in parentheses indicate the standard errors of the associated coefficients

* * d is the Von-Neumann ratio.

the regression equation a change of 0.1 in log $\frac{P_{T(t)}}{P_{L(t-1)}}$ means a change in G_t of $3.795 . 10^3$. A change of 0.1 in log $\frac{P_T}{P_{L(t-1)}}$ is roughly equivalent to a 10.5% change in the level of log $\frac{P_T}{P_{L(t-1)}}$. Thus the arc elasticity at the mean level of sales is slightly less than 0.95. More importantly, a 10% change in the price ratio means an estimated change in the level of sales of around 3,700 to 3,800 units at any level of sales.[1]

N.B. The rate of interest + 1%; the average price of tractors compared to the lagged price of crops; lagged farm size and total advertising expenditure were all non-significant and added nothing to the explanatory power of the regression equations.

2. Stock Adjustment

The stock adjustment models explaining the demand for tractors in terms of units are much more satisfactory statistically than the gross investment models. Table (2) summarises the better results.[2] E

Equation (1) corresponds to the stock adjustment model $S_t = g' S_t^* + (1-g') S_{t-1}$ and has all the coefficients signifcant at the 5% level. The indicated adjustment coefficient g' is 0.55, suggesting that farmers adjust actual stock of tractors quite quickly to short run changes in average tractor prices compared

1. This does not mean however that a 20% change in the price ratio results in a doubling of the number of units sold compared to the 10% change. There is a curvilinear relationship between the two; it takes a 170% change in price ratio to be associated with a change of 38,000 units sold.
2. The high $\overline{R}^2$ in equations where stock is a function of lagged stock cannot be taken literally as indicative of a good fit because of the high intercorrelation between stock and its lagged value. The significance of the coefficients is the important statistical consideration.

to labour earnings and the quality of new tractors available. The estimate of the short and long run elasticities of stock at the mean level of stock ($37.087 \; . \; 10^4$) are:-

		short run	long run[1]
1) with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$	=	-0.21	-0.40
2) with respect to Q_t	=	+0.25	+0.46

Alternatively the coefficients of the equation indicate that a 10 change in the price ratio would lead to a change in the actual stock in one year of around 7,800 units and a change in the desired stock of roughly twice this - 15,000 units.

Similarly, a 10% change in the quality change index indicates a change in actual stocks of around 9,400 units and a change in desired stocks of around 18,000 units.

Equation (2) shows the same variables but in log form and corresponds to the model $\log S_t = g' \log S_t^* + (1-g')\log S_{t-1}$. However, this model must be rejected in this case in favour of the simple adjustment model represented by equation (1). The $\bar{R}^2$ is reduced and $\log \frac{P_{T(t)}}{P_{L(t-1)}}$ is just non-signifivant at the 5% level. However, it is interesting to note that the constant term is now significant. This can be taken to mean that there is a significant trend term in equation (2) represented by part of the constant term.

The introduction of the other economic variables, $R_t + 1\%$ and $\frac{P_{T(t)}}{P_{C(t-1)}}$ made no improvement to the regression. Thus $R_t + 1\%$ was added to a linear

1. Obtained by dividing the short run elasticities by g'.

TABLE 2

Regression Equation Explaining

Stock Adjustment by Numbers

Equation	1	2
Definition of the Dependent Variable	Stock in t (10^4)	Log_e Stock in t (10^4)
Constant	16.18 (11.50)	1.456 (0.400)
$Log_e \left(\frac{P_{T(t)}}{P_{L(t-1)}}\right)$	-7.898 (3.068)	-0.1402 (0.0771)
$Log_e\ Q_t$	9.420 (2.560)	0.2234 (0.0606)
S_{t-1}	0.4530 (0.1210)	
$Log_e\ S_{t-1}\ (10^4)$		0.5088 (0.0883)
$\bar{R}^2$	0.993	0.991
d	1.53	1.53

$\frac{P_{T(t)}}{P_{L(t-1)}}$ = ratio of index of average price of tractors (t) to index of labour earnings (t-1)

Q_t = Index of quality change in t.

S_{t-1} = Stock by numbers (10^4) in (t-1).

regression function with the following result:-

$$\text{Stock in (t) by } 10^4 = \underset{(3.97)}{8.46} - \underset{(0.028)}{0.014} \frac{P_{T(t)}}{P_{L(t-1)}} + \underset{(0.262)}{0.122} R_t + 1\% + \underset{(0.028)}{0.042} Q_t$$

$$+ \underset{(0.11)}{0.72} \text{ Stock}_{t-1} \qquad \bar{R}^2 = 0.988 \qquad d = 1.69$$

Thus $R_t + 1\%$ has the wrong (i.e. positive) sign and was non-significant. Likewise addition of $\frac{P_{T(t)}}{P_{C(t-1)}}$ did not improve the fit and the variable was non-significant with the wrong (i.e. positive) sign.

B. Results with the Dependent Variable expressed as Deflated Value

The price ratios used to explain the dependent variable in deflated value terms refer to the 'real' price of tractors. The lagged stock variable is measured in value terms deflated by the real price of tractors index.

1. Gross Investment

Table 3 summarises the more useful results of a semilogarithmic type. Over 90% of the variation in gross investment is explained by all the formulations of the gross investment function. Equation (1) is satisfactory, with $\frac{P_{T(t)}}{P_{L(t-1)}}$ being significant at the 5% level and % investment allowance not quite significant. However, there is a high degree of correlation between the price ratio and % investment allowance ($r^2 = -0.73$) and therefore the % investment allowance may possible be taken as being an important influence on gross investment. The estimated elasticities of gross investment with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$ and % investment allowance from this equation are -0.88 and +0.04 at the mean level of gross investment (£22.11 m.). Alternatively, at any level of sales, the coefficients imply that a 10% change in the price ratio would lead to a change in deflated sales of about £1.9 million; a 10% change in the % investment allowance[1] implies

1. i.e. if investment allowance in 20%; then a 10% change means a change of 2% in the actual level.

a change in deflated sales of around £0.09 million.

Equation (2) through to (6) represent attempts to improve the simple investment function of (1) but none are any more satisfactory. Log $\frac{P_{T(t)}}{P_{C(t-1)}}$ is non-significant and has the wrong sign in (2). This is probably partly a result of the very high simple correlation between $\frac{P_{T(t)}}{P_{L(t-1)}}$ and $\frac{P_{T(t)}}{P_{C(t-1)}}$; however log $\frac{P_{T(t)}}{P_{L(t-1)}}$ is dominant and retains its significance in the equation. Evidence for this is provided by equation (6) where log $\frac{P_{T(t)}}{P_{C(t-1)}}$ has the correct sign and is significant when log $\frac{P_{T(t)}}{P_{L(t-1)}}$ is omitted. The elasticity of gross investment with respect to $\frac{P_{T(t)}}{P_{C(t-1)}}$ at the mean of sales is -0.65; alternatively, at any level of sales, the coefficient indicates that a 10% change in the price ratio would lead to a change in deflated sales of about £1.4 million.

In equation (3) the interest rate plus 1% variable is added to equation (1). Although of the correct sign it is non-significant and only marginally improves the explanatory power of the regression. The significance of the other two variables is reduced because of the high intercorrelations between the three variables. It is likely that in fact R + 1% is a significant influence on gross investment, by deflated value, but because of the multicollinearity problem this cannot be picked out. Thus, in equation (3), it has a much higher F value than % investment allowance. The estimated coefficient indicates that a 20% increase in R + 1% (in real terms for example, an increase from 4 + 1% to 5 + 1%) leads to a drop in sales of £1 m. (deflated). The elasticity at the mean of sales

TABLE 3. Regression Equations explaining Gross Investment by Deflated Value

Equation	Dependent Variable	Constant	$\log_e \frac{P_{T(t)}}{P_{c(t-1)}}$	$\log_e \frac{P_{T(t)}}{P_{L(t-1)}}$	$\log_e R_t + 1\%$	$\log_e I_t$	$\log_e F_{(t-1)}$	$\log_e V_t$	$\log_e S_{t-1}$	$\bar{R}^2$	d
(1)	Gross Investment (£m. deflated)	115.2 (12.8)		-19.47 (2.49)		0.9160 (0.5770)				0.92	1.67
(2)	Gross Investment (£m. deflated)	109.0 (19.8)	2.61 (6.160)	-20.73 (3.91)		0.879 (0.600)				0.91	1.72
(3)	Gross Investment (£m. deflated)	151.4 (32.5)		-24.89 (5.11)	-5.709 (4.730)	0.470 (0.678)				0.92	1.97
(4)	Gross Investment (£m. deflated)	156.6 (65.6)		-25.57 (8.99)	-5.625 (4.945)	0.493 (0.744)		-0.651 (6.99)		0.91	1.98
(5)	Gross Investment (£m. deflated)	120.1 (64.5)		-21.42 (8.07)	-3.83 (5.88)	0.525 (0.701)	8.619 (15.22)			0.92	1.99
(6)	Gross Investment (£m. deflated)	24.8 (34.1)	-14.4 (6.30)		3.42 (4.00)	1.004 (0.649)	4.47 (1.06)			0.91	2.09
(7)	Gross Investment (£m. deflated)	344.5 (90.2)		-55.23 (14.13)		1.163 (0.502)			-27.50 (10.70)	0.94	1.84
(8)	Gross Investment (£m. deflated)	340.2 (96.8)	0.9098 (5.3460)	-55.34 (14.66)		1.148 (0.528)			-27.25 (11.23)	0.94	1.83

$\frac{P_{T(t)}}{P_{c(t-1)}}$ = index of 'real' price of tractors (t)/index crop prices (t-1)

$\frac{P_{T(t)}}{P_{L(t-1)}}$ = index of real price of tractors (t)/index labour earnings (t-1)

$I_t + 1\%$ = weighted average of bank rate (t) + 1%

I_t = % investment allowance in t.

F_{t-1} = farm size (t-1) (%

V_t = advertising expenditure t (£10^4)

S_{t-1} = stock t-1 in 10 £m. (deflated) is -0.25. However because the estimation of the coefficient is not too exact these figures are only very approximate and have no statistical significance. They do however indicate that the influence of bank rate changes is fairly small unless the rate changes quite markedly.

Equation (4) represents an attempt to include advertising expenditure in the gross investment function. However, again there is a multicollinearity problem; the variable has the wrong sign and is non-significant. In equation (5) and (6) farm size is introduced; in both equations the constant is non-significant, previously it was significant. This implies that farm size is a trend variable; on inclusion it removes the trend element from the constant term.[1] In equation (6) it becomes significant with the omission of log $\frac{P_{T(t)}}{P_{L(t-1)}}$. The size of the coefficient indicates that a 20% increase in the variable leads to a rise in gross investment (deflated) of £0.8 m. per annum. This may be taken as an average value of the upward trend.

Equations (7) and (8) represent the more comprehensive gross investment model $G_t = g\ (\log S_t^* - \log S_{t-1})$ whereby investment is a response to the stimulus of a disequilibrium between desired stock and lagged stock. In (7) where log of lagged stock has been added for equation (1) the $\bar{R}^2$ has been improved and all three variables are significant at the 5% level. Hence (7) offers a better explanation of gross investment than the more simple functions. The coefficient of $\frac{P_{T(t)}}{P_{L(t-1)}}$ is greatly increased compared to equation (1) and now implies that a 10% fall in the price ratio would increase sales by £5.5 million (deflated). The elasticity

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1. If trend is simple arithmetic trend (D) then $e^{G_t} = a_o X_1^{b_1} X_2^{b_2} D^1$

therefore $G_t = \log a_o + b_1 \log X_1 + b_2 \log X_2 + 1 \log D$

$$= (\log a_o + \log D) + b_1 \log X_1 + b_2 \log X_2$$

of gross investment with respect to the price ratio, at the mean of gross investment, is more than doubled being -2.52 now. That with respect to the % investment allowance in +0.05 and with respect to lagged stock is -1.24. The coefficient of the lagged stock variable further implies that a 10% rise in lagged stocks tends to reduce gross investment by £2.7 million (deflated). This coefficient is also the response coefficient g implying that:-

$$G_t = 27.5 \left(\log S_t^* - \log S_{t-1}\right)$$

If we assume that $\log S_t^* = a + b \log \frac{P_{T(t)}}{P_{L(t-1)}}$.

Then b is the elasticity of desired stock with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$ and is obtained by dividing the coefficient of $\log \frac{P_{T(t)}}{P_{L(t-1)}}$ in the gross investment equation by g. This gives the elasticity of desired stock with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$, which is - 2.03. Investment allowances were assumed not to enter the desired stock equation. The function implies that disequilibrium between desired stock and actual stock rises from 40% in 1948 to over 200% by 1965. This is estimated from the level of sales in those years.[1]

The estimated % disequilibrium and the estimated desired stock elasticity seem fairly unrealistic and cast doubt on the way lagged stock has been introduced into the function. In particular, the exponential growth of the disequilibrium is unrealistic. Thus it seems better to conclude, that lagged stock is important in explaining gross investment but not in the explicit manner proposed by the

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1. Thus $G_t = g\left(\log S_t^* - \log S_{t-1}\right)$

therefore $\frac{G_t}{g} = \log S_t^* - \log S_{t-1}$

therefore $\text{antilog}\left(\frac{G_t}{g}\right) = \frac{S_t^*}{S_{t-1}}$

investment function (5b). Rather all that can be said, without formulation of a different model, is that the increasing level of stock in t-1 depresses gross investment in t. Because the log of lagged stock is used then this implies that the change in gross investment between t-1 and t depends on the percentage change in stocks in t-1; that is on both the net investment in t-1 and on the level of stocks at the end of t-1. Thus a negative coefficient is expected, since a rising stock level is continually tending to depress the marginal physical product from the input of tractor services. Thus a high level of stocks at the end of t-1 tends to depress gross investment; further, a large increase in net investment in t-1 will also tend to depress gross investment.

2. Stock Adjustment

Table 4 summarises the better results; the % investment allowance variable has been introduced as possibly affecting the actual level of stocks - it does not belong to the desired stock function. Thus, if it encourages replacement by a higher quality machine, or if it encourages earlier replacement, it affects the adjustment process of actual stock toward desired stock.

Equation (1) was a linear formulation[1] to give the R + 1% variable a chance to perform. However although it has the correct sign it is not quite significant. If it is assumed, that this is because of its high intercorrelation with the other variables, then we might estimate the elasticity as a valid concept. The short run stock elasticity at the means of stocks (£91.92 m) and R + 1% (5.16) is -0.12. The estimated desired stock elasticity is given by dividing by the adjustment coefficient g'. The coefficient of lagged stock = 1-g'

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1. $S_t = g'S_t^* + (1-g')S_{t-1}$.

therefore $g' = 0.22$, therefore the long run elasticity of stock to the rate of interest is -0.54 at the mean.

A logarithmic formulation[1] of the same model improves the explanatory power but the R + 1% variable now has a standard error bigger than its coefficient in log form. The adjustment coefficient is markedly increased and the significance of investment allowances increased. This indicates, that the hypothesis, that a percentage change in stock is some proportion of the % disequilibrium between desired and actual stock fits the data better than the hypothesis concerning absolute changes. Equation (2) is improved by the inclusion of $\log_e \frac{P_{T(t)}}{P_{C(t-1)}}$ which has the correct sign and is significant. In both equations (2) and (3) $\log R_t + 1\%$ is non-significant and has the wrong sign. Dropping this variable from (3) leaves equation (4) where all variables are significant and the regression has an improved fit compared to the other proposed functions. The adjustment coefficient is estimated as 0.68 which suggests that farmers adjust stocks quite quickly to short run changes in the two price ratios. The % investment allowance variable is significant and positive indicating that the rate of adjustment is increased by these allowances. The short run elasticities of stock are given directly; the long run elasticities are given by dividing by the adjustment coefficient:-

	short run	long run
1) wuth respect to $\frac{P_{t(t)}}{P_{C(t-1)}}$	-0.24	-0.35
2) with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$	-0.66	-0.97
3) with respect to I_t	+0.01	*

1. $\log_e S_t = g' \log_e S_t^* + (1-g')\log_e S_{t-1}$

* % investment allowances are assumed not to affect desired stock; only the adjustment process.

TABLE 4

Regression Equation Explaining Stock Adjustment by Deflated Value

Equation	1	2	3	4
Definition of the Dependent Variable	Stock in t (£10m deflated)	Log_e Stock in t (£10m deflated)	Log_e Stock in t (£10m deflated)	Log_e Stock in t (£10m deflated)
Constant	6.33 (1.83)	4.619 (1.448)	5.734 (1.018)	5.785 (0.987)
$\frac{P_{T(t)}}{P_{L(t-1)}}$	-0.0197 (0.006)			
I_t	0.003 (0.012)			
$R_t + 1\%$	-0.212 (0.151)			
S_{t-1}	0.776 (0.089)			
$\text{Log}_e \frac{P_{T(t)}}{P_{c(t-1)}}$			-0.2316 (0.0572)	-0.2385 (0.0545)
$\text{Log}_e \frac{P_{T(t)}}{P_{L(t-1)}}$		-0.6833 (0.2267)	-0.6573 (0.1535)	-0.6584 (0.1496)
$\text{Log}_e R_t + 1\%$		0.0660 (0.068)	0.0275 (0.0471)	
$\text{Log}_e I_t$		0.0130 (0.0101)	0.0135 (0.0067)	0.01134 (0.00530)
$\text{Log}_e S_{t-1}$		0.3416 (0.1784)	0.3044 (0.1210)	0.3211 (0.1146)
$\bar{R}^2$	0.992	0.994	0.997	0.998
d	1.84	1.23	2.29	2.38

$\frac{P_T}{P_{L(t-1)}}$ = index of real price of tractors (t)/index of labour earnings (t-1).

$\frac{P_{T(t)}}{P_{c(t-1)}}$ = index of real price of tractors (t)/index of crop prices (t-1).

$R_t + 1\%$ = weighted average of bank rate in t + 1%.

I_t = % investment allowance in t.

S_{t-1} = Stock in t-1 by deflated value (£10m).

The elasticity of stock with regard to % investment allowance is interesting; if % investment allowance is increased by 50% (for example from 20% allowance to 30% allowance) then stock is increased by 0.5%. This is beyond the stock change caused by the adjustment process.

The long run elasticity with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$ contrasts sharply with that obtained from the gross investment equation; again suggesting that lagged stock was not introduced into the gross investment equation in the correct manner.

Finally the estimated elasticities of stock with respect to the two price ratios are fairly low in the short run and still less than unity in the long run. It is to be expected with a high adjustment rate - that they are close together. It also seems reasonable that if the elasticities of desired stock are low a high adjustment rate will occur since the level of desired stock does not respond much to price changes. Thus farmers can be fairly sure of the desired level. The high adjustment coefficient,of stock change toward desired stock,also indicates that the % disequilibrium between $S_t{}^*$ and S_{t-1} generated by the gross investment model is too large and that the model was incorrectly formulated.

C. <u>Where the Dependent Variable is Measured in terms of Total Horse-Power</u>

The price ratios used to explain the dependent variable in terms of total horse-power refer to average price per tractor h.p. Lagged stock refers to lagged stock in terms of horse-power.

1. <u>Gross Investment</u>

The variable $\frac{P_{T(t)}}{P_{L(t-1)}}$ dominates all of these regressions (given in Table 5).

Alone it accounts for 90% of the variation in gross investment by total horse power - equation (1). A 10% fall in the ratio of price of tractor h.p. to labour earnings is associated with an increase in gross investment of $1.63.10^5$ h.p. The elasticity of demand for h.p. with respect to this price ratio is more than unity at the mean of sales; being -1.14.

The explanatory power of the regression is improved by including $R_t + 1\%$ and using a linear formulation. $R_t + 1\%$ is significant as well as $\frac{P_{T(t)}}{P_{L(t-1)}}$ at the 5% level. (However in a semilog form $R_t + 1\%$ is non-significant). The elasticities of gross investment, calculated from equation (2), at the means[1] of gross investment and the two explanatory variables are:-

1) with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$: -1.46

2) with respect to $R_t + 1\%$: -0.36

Because the interest rate variable is itself a percentage the elasticity indicates that a change of 1% in the actual bank rate, from 4% to 5%, would lead to a fall in sales of total horse power of 7.2%.

Equations (3) to (7) represent attempts to improve on equation (1) by introducing other explanatory variables. All however are non-significant, whilst $\log \frac{P_{T(t)}}{P_{L(t-1)}}$ remains significant and the total explanatory power is not improved. In contrast to regressions with the other dependent variables, the farm size proxy variable does not make the constant non-significant, although its significance does decrease when the farm size variable is introduced. Advertising expenditure (equation (51)is non-significant and has the wrong sign; it does however have a

1. Mean of G_t = 14.29

Mean of $\frac{P_{T(t)}}{P_{L(t-1)}}$ = 122.7

Mean of $R + 1\%$ = 5.16

TABLE 5. Regression Equations Explaining Gross Investment by Total Horsepower.

Equation	Definition of the Dependent Variable	Constant	$\frac{P_{T(t)}}{P_{L(t-1)}}$	$\log_e \frac{P_{T(t)}}{P_{L(t-1)}}$	$R_t + 1\%$	$\log_e I_t$	$\log_e F_{(t-1)}$	$\log_e V_t$	$\log_e S_{t-1}$	$\bar{R}^2$	d
(1)	Gross Investment h.p. (10^5)	92.06 (6.37)		-16.28 (1.33)						0.90	2.16
(2)	Gross Investment h.p. (10^5)	40.27 (4.36)	-0.1701 (0.0180)		-0.9900 (0.4296)					0.91	2.23
(3)	Gross Investment h.p. (10^5)	81.40 (9.45)		-14.22 (1.90)		0.4864 (0.3147)				0.91	1.799
(4)	Gross Investment h.p. (10^5)	92.00 (16.92)		-16.32 (2.64)			0.158 (4.070)			0.89	2.11
(5)	Gross Investment h.p. (10^5)	94.80 (3.42)		-16.68 (4.39)				-0.164 (2.380)		0.89	1.93
(6)	Gross Investment h.p. (10^5)	121.2 (35.2)		-20.92 (5.67)					-3.040 (3.608)	0.90	2.22
(7)	Gross Investment h.p. (10^5)	121.2 (32.9)		-20.45 (5.31)		0.5580 (0.3154)			-4.392 (3.462)	0.91	1.90

$\frac{P_{T(t)}}{P_{L(t-1)}}$ = index of average price per h.p. in t/index of labour earnings in t-1.

$R_t + 1\%$ = Bank rate + 1% (t).

I_t = % Investment allowance.

$F_{(t-1)}$ = Proxy for farm size in (t-1).

V_t = advertising expenditure in t in £10^4.

S_{t-1} = stock by h.p. (10^6) in t-1.

very high intercorrelation with $\frac{P_{T(t)}}{P_{L(t-1)}}$ and its effect may be masked. The same problem arises with the introduction of the log of lagged stock into the regression. Lagged stock is very highly correlated with $\frac{P_{T(t)}}{P_{L(t-1)}}$ and because of this, the separate influences of the two variables cannot be distinguished. In equation (1), the coefficient of $\frac{P_{T(t)}}{P_{L(t-1)}}$ probably picks up some of the influence that should be ascribed to lagged stocks. In (7) there is probably some indeterminacy involved in the estimation of the coefficients because of the multicollinearity problem. As far as prediction is concerned, both equations are equally good, whilst the trend between the two variables continues. If this trend is broken then (7) should give better predictions since it is a better structural equation - if we accept that lagged stock has some influence on gross investment. The introduction of the log of lagged stock raises the coefficient of log $\frac{P_{T(t)}}{P_{L(t-1)}}$. Thus, the coefficient of log $\frac{P_{T(t)}}{P_{L(t-1)}}$ in (7) associates a 10% fall in the price ratio with an increase in sales of $2.05.10^5$ h.p. The elasticity of gross investment with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$ is raised to -1.43. The log of I_t is not quite significant in equation (7); although its F value is raised by the introdution of stock. The coefficient of I_t indicates that a 50% increase in the investment allowance say from 20% to 30%, is associated with an increase in sales of $0.22.10^5$ h.p.[1] If we similarly accept that the coefficient of the log of lagged stock is valid, then a 10% rise in lagged stock is associated with a fall in gross investment of 0.4×10^5 h.p.

The price ratio, price of tractor h.p. to lagged crop prices, was non-significant and has the wrong sign when tried in the regression equation. Since it is not

1. An increase in log I_t by 0.4 is equivalent to a rise in I_t of 50% of the original value.

highly intercorrelated with the other explanatory variables then it can be said to have no influence on gross investment by h.p.

2. Stock Adjustment

Table 6 indicates the better results from testing the stock adjustment formulae. It is difficult to pick out the exact value of the adjustment coefficient g^1 as no one regression is 'best' and its value changes with the regression formula. Thus it varies from 0.13 in equation (1) to 0.33 in equation (4). Equation (1), the linear formulation of stock adjustment,[1] has the best fit but the coefficient of $R_t + 1\%$ is non-significant. The estimated short run elasticity of stock with respect to $\frac{P_{T(t)}}{P_{L(t-1)}}$ at the means is -0.21 and the corresponding long run elasticity is -1.61.

In equation (2), which explains stock adjustment in percentage terms[2], changes in desired stock are explained simply by $\frac{P_{T(t)}}{P_{L(t-1)}}$. The adjustment coefficient is increased to 0.23. The short run stock elasticity is constant for any level of stock or price ratio and is estimated as -0.26 and the long run elasticity is -1.13.

Using $\log I_t$ as an additional explanatory variable in (3) means that the adjustment coefficient is increased, as expected, but the coefficient of $\log I_t$ is non-significant. In (4) $\log R_t + 1\%$ is also introduced but it has the wrong sign and is non-significant. However again the adjustment coefficient is increased.

In summary the equations indicate an adjustment coefficient of around 0.25, suggesting that farmers adjust stock, by horse power, fairly slowly to short run changes in the price ratio of cost per h.p. to labour earnings. The estimated

1. $S_t = g' S_t^* + (1-g') S_{t-1}$.
2. $\log S_t = g' \log S_t^* + (1-g') \log S_{t-1}$.

TABLE 6. Regression Equations Explaining Stock Adjustment by Total Horse Power

Equation	1	2	3	4
Definition of the Dependent Variable	Stock of h.p. in t (10^6)	$\log_e$ Stock of h.p. in t (10^6)	$\log_e$ Stock of h.p. in t (10^6)	$\log_e$ Stock of h.p. in t (10^6)
Constant	4.743 (1.774)	1.859 (0.599)	2.150 (0.760)	2.280 (0.760)
$\frac{P_{T(t)}}{P_{L(t-1)}}$	-0.0196 (0.0083)			
$R_t + 1\%$	-0.0250 (0.0680)			
S_{t-1}	0.8673 (0.0573)			
$\log_e \frac{P_{T(t)}}{P_{L(t-1)}}$		-0.2609 (0.0964)	-0.3075 (0.1240)	-0.3268 (0.1226)
$\log_e R_t + 1\%$				0.0670 (0.0552)
$\log_e I_t$			0.0053 (0.0076)	0.0105 (0.0086)
$\log_e S_{t-1}$		0.7678 (0.0614)	0.7352 (0.0802)	0.6676 (0.0967)
$\bar{R}^2$	0.997	0.996	0.993	0.994
d	2.35	1.69	2.12	2.16

$\frac{P_{T(t)}}{P_{L(t-1)}}$ = index of average price per tractor h.p./index of labour earnings in (t-1).

$R_t + 1\%$ = weighted average of bank rate in t + 1%.

I_t = % investment allowance in t.

S_{t-1} = stock of h.p. in t-1 (10^6).

short run stock elasticity with respect to this price ratio is around -0.25 and the long run elasticity just over -1.0.

D. Where the Dependent Variable is measured in terms of Weighted Numbers

The relevant price ratios to the dependent variable measured by weighted numbers refer to the average price per tractor sold. Lagged stock refers to lagged stock measured by weighted numbers.

1. Gross Investment

Gross investment by weighted numbers is most satisfactorily explained by equation (1) out of the formulated regression listed in Table 7. 70% of the variation in gross investment is explained by two variables: the price ratio, average price of tractors to labour earnings and investment allowances. Both are significant at the 5% level. The coefficient of the price ratio variable indicates that a 10% fall in the price ratio is associated with increased gross investment of around $6.23.10^{8}$ weighted tractor units.[1] At the mean of gross investment, the elasticity of gross investment with respect to the price ratio is -1.40. The similar elasticity, with respect to % investment allowances, is +0.077. More meaningfully, a 50% increase in the level of investment allowances (say from 20% to 30%) is associated with an increase in sales of 1,200 tractor units. An increase from no investment allowance - allowed at 1% - to 20% investment allowance[2] is associated with an increase in sales of around 9,000 weighted units.

The log of the price ratio, price of large tractors to price of small tractors,

1. This corresponds to about 4,000 units all weighted by 1.5 (i.e. in the >40 h.p. group) or 6,000 weighted by 1.0 - compare effect of same % price change in equations explaining gross investment by numbers - leads to change in gross investment of around 3,800 units.
2. Equal to an increase of 3.0 in $\log_e . I_t$.

is added to (1) to give equation (2). This variable has the correct sign but is non-significant. Similarly, adding the log of the proxy varaible for farm size to (1) in (3) does not improve the regression and the variable is non-significant. In (4) the log of $R_t + 1\%$ is added to regression (1) but has the wrong sign and is non-significant. However, if $\log I_t$ is removed from the regression equation and these other variables - $R_t + 1\%$, F_{t-1} and $\frac{P_{L.T.(t)}}{P_{S.T.(t)}}$ left in, the latter two are just significant and R + 1% now has the right sign - equation (7). This indicates that these variables are sensitive to the inclusion of $\log I_t$; when this is removed their coefficients increase in size and give the elasticities at the mean of gross investment:-

1) with respect to F_{t-1} : 0.55

2) with respect to $\frac{P_{L.T.(t)}}{P_{S.T.(t)}}$: -0.45.

The interest variable is non-significant however. But the regression does not explain gross investment, by weighted numbers, as well as equation (1); further because of collinearity, these variables may pick up some of the influence that that should be attributed to I_t.

In equation (5), advertising expenditure is significant in explaining gross investment; the coefficient indicates that a 10% increase in the level of total advertising expenditure is associated with an increase in sales of 1,700 weighted tractor units. At the mean of gross investment, this represents an elasticity of 0.40. However, the regression does not have as high an $\bar{R}^2$ as equation (1). This variable is also sensitive to the introduction of $\log I_t$: thus in equation (6) it becomes non-significant. Finally in equation (8) the log of lagged stock is introduced into equation (1). It is both non-significant and has the wrong sign.

TABLE 7. Regression Equations explaining Gross Investment by Weighted Number

Equation	Definition of the Dependent Variable	Constant	$Log_e \frac{P_{T(t)}}{P_{L(t-1)}}$	$Log_e R_t + 1\%$	$Log_e I_t$	$Log_e F_{t-1}$	$Log_e V_t$	$Log_e \frac{P_{L.T(t)}}{P_{S.T(t)}}$	$Log_e S_{t-1}$	$\bar{R}^2$	d
(1)	Gross Investment weighted numbers (10^3)	327.7 (90.7)	-61.68 (19.26)		3.405 (0.8123)					0.70	1.55
(2)	Gross Investment weighted numbers (10^3)	345.7 (97.8)	-62.30 (19.7)		3.100 (1.03)			-3.000 (5.10)		0.69	1.63
(3)	Gross Investment weighted numbers (10^3)	321.2 (111.0)	-60.60 (22.3)		3.380 (1.12)	1.20 (11.60)				0.68	1.55
(4)	Gross Investment weighted numbers (10^3)	318.1 (94.98)	-60.39 (19.93)	2.42 (4.80)	3.216 (0.918)					0.69	1.60
(5)	Gross Investment weighted numbers (10^3)	219.0 (112.0)	-53.8 (28.3)	-11.90 (8.20)			17.50 (5.60)			0.65	1.94
(6)	Gross Investment weighted numbers (10^3)	286.1 (130.7)	-56.21 (21.89)		2.541 (1.274)		4.526 (6.403)	0.58 (7.30)		0.68	1.68
(7)	Gross Investment weighted numbers (10^3)	416.2 (141.9)	-60.0 (25.6)	-15.0 (11.3)		24.3 (12.4)		-19.8 (9.8)		0.58	1.94
(8)	Gross Investment weighted numbers (10^3)	297.3 (106.0)	-58.22 (20.54)		2.931 (1.158)				4.191 (7.064)	0.69	1.63

$\frac{P_{T(t)}}{P_{L(t-1)}}$ = index of average price of tractors (t)/index of labour wage earnings (t-1).

$R_t + 1\%$ = bank rate + 1% (t).

I_t = % investment allowance (t).

F_{t-1} = Proxy for farm size (t-1).

U_t = advertising expenditure in t £10^3.

$\frac{P_{L.T(t)}}{P_{S.T(t)}}$ = index average price large tractors ÷ index average price small tractors.

S_{t-1} = stock in t-1 measured by weighted numbers.

In summary, equation (1) offers the best explanation of gross investment; the two variables $\log \frac{P_{T(t)}}{P_{L(t-1)}}$ and $\log I_t$ explaining 70% of the variation in gross investment. Other influences are indicated to be important but only when $\log I_t$ is excluded. The price ratio of average tractor prices to lagged crop prices was found to be non-significant when used in the regressions.

2. Stock Adjustment

No satisfactory stock adjustment equations were obtained; only lagged stock was found to be significant. This is indicated by the following equation:-

$$\log_e S_t = \underset{(0.575)}{1.250} - \underset{(0.112)}{0.128} \log_e \frac{P_{T(t)}}{P_{L(t-1)}} + \underset{(0.0063)}{0.0102} \log_e I_t$$

$$+ \underset{(0.038)}{0.829} \log_e S_{t-1} \qquad \bar{R}^2 = 0.987 \qquad d = 1.61$$

where S_t = Stock by weighted numbers (10^4) in t

S_{t-1} = Stock by weighted numbers (10^4) in t-1

$\frac{P_{T(t)}}{P_{L(t-1)}}$ = Index of average price per tractor (t)/index of labour earnings (t-1)

I_t = % investment allowance in t

Thus a very low adjustment coefficient of 0.17 is indicated. However the coefficient of the price variable is non-significant, desired stock is simply estimated to be constant.[1] The coefficient of the % investment allowance variable is also non-significant, which implies that stock of weighted numbers increases by a constant percentage each year toward some constant desired stock level.

The estimated stock adjustment regression equations in fact seem quite unrealistic; since they indicate that stock levels are not affected by economic

1. $\log_e$ of the desired stock constant = 7.350 therefore estimate of desired stock is 156.10^4 weighted tractor units.

or financial variables. This may be partly due to the fact, that as already indicated, the weighted numbers estimation of stock may be in error - more so than in the case of any other stock measure.

N.B.

1. A limited number of regressions were tested to explain gross investment, as the adjustment, to a disequilibrium between an equilibrium level of gross investment as determined by economic forces, and gross investment in the previous year. However, lagged gross investment was always non-significant; further the explanatory power of the regressions was reduced by its introduction. Therefore it was considered that this model was not relevant to the demand for tractors.

2. The trend in purchases toward larger tractors was looked at to a limited extent, following the importance in the regressions of the substitution of tractors for labour in explaining the demand for tractors. This trend represents to some extent the substitution of capital for capital and seems to be largely associated with the % increase in farm size (as represented by the proxy variable) and the level of investment allowances. Increased farm size allows greater use of mechanisation and an increased demand per acre for tractor services; this is provided most profitably by an increased size of tractor. Investment allowances provide a short-run incentive as to when the replacement of a smaller by a larger tractor should occur.

7. Limitations of the Results

Conclusions from the results are limited by three factors. Firstly, the data used is historical and therefore we have to ask how relevant are our estimated relationships to present conditions? This is particularly so with reference to prediction. Also, the estimated structural equations may be "hybrids" - if conditions surrounding the investment in tractors have changed very much over the time period. Since quality change has been explicitly taken into account then this is not likely to be too important.

Secondly, the algebraic formulations chosen to represent the structural equations are to some extent arbitrary. Thus, they may not entirely represent structural equations, although some evidence is provided by their statistical fit.

Thirdly, the data used has its own limitations. Thus the data used for the dependent variables, either as gross investment or stock, contains some element of error with reference to the definition of the dependent variable. Also the data for some variables is not on the calendar year as the gross investment variable is defined. Thus the labour earnings variable refers to a June to May year; the U.K. net farm income variable is on a similar basis. The position is further complicated in the stock adjustment function where end of year stock is in fact a hybrid between a September and a December figure. Another possible data limitation, is that of errors in the explanatory variables. This may arise in connection with the tractor price indices. Thus list price may not always represent the average price of tractors sold; 'real' price was estimated using regression techniques subject to error, and the statistical series used are subject to errors of collation. Finally, some variables are used as proxy for the proper structural variables. Thus the crop price and net farm income variables were used to represent expected earnings; the percentage of farms over 300 acres was used to represent the trend in farm size. Thus equations containing these proxy variables are not 'true' structural equations; they will only be satisfactory so long as the unspecified relationship of these proxies to the true causal variables remains unchanged.

8) <u>Conclusions</u>

The results from this analysis emphasise that the demand for wheeled farm tractors by U.K. agriculture, over the past eighteen years, has been concerndd with capital 'deepening'. With respect to both the desired level of stocks and gross investment, the price ratio of tractors to labour is the dominating explanatory variable in the regressions.

At the mean level of gross investment, thd percentage changes in gross investment have been somewhat more than the percentage changes in the price ratio - the elasticity is between -1.0 to -2.0; the percentage changes in stocks have been somewhat less than the corresponding percentage changes in the price ratio. Since the stock level, and therefore the input of services from tractors, has been increased over the period while the labour input has decreased it can be concluded that tractor services have been substituted for labour services in response to changes in their relative prices. Thus the increased use of capital, in the form of tractors, has been toward increasing the capital intensity of farm operations as a direct consequence of profit maximising behaviour. This is a very different result to those from analyses of investment behaviour in manufacturing industries. These have emphasised capital 'widening' not always under the influence of the profit motive, with a secondary role played by lagged profits as an expectational and financial variable. The divergence is probably partly because of differences in industry structure; partly because this analysis deals with disaggregated investment. The results also differ from those other studies into investment behaviour in agriculture, even at the disaggregated investment level. These, - Griliches (7), Cromarty (8), and Heady and Tweeten (25) emphasised that the price of the capital input (either tractors or farm machinery as a whole) in relation to expected earnings (as represented by lagged product prices) was the important determinant of farm investment behaviour with respect to the input. However, these were all studies of U.S. agriculture.

Although the dominating feature of the regressions is that of the importance of the price of tractors relative to the price of labour, several other points stand out. In particular, the importance of quality to the gross investment function - the more explicitly quality is taken account of, by the dependent variable, the more can gross investment be explained and the less influence the stochastic effect has. That quality change has been important, with regard to farm purchase of tractors, is shown by the importance of the quality change index in explaining the desired stock of tractors by number. The higher the quality, the higher the desired stock, because the marginal physical product curve from the tractor services input is increased. However, in the gross investment function, by numbers, the quality change index is not quite significant. There are two conclusions to be drawn from this. Firstly, although increasing quality tends to raise the level of desired stock by numbers, and therefore the actual stock, as far as replacement is concerned it will tend to depress the number of tractor units bought. Thus on gross investment there are two opposing influences. Secondly, gross investment by number could not be explained at all satisfactorily. The explanatory power of the regressions was low and only one variable - the average price of tractors relative to the cost of labour was significant - and then only in the presence of the lagged stocks variable. Hence the demand for tractors, in terms of numbers, was not at all rational. From this and the importance of the quality change index it is apparent that farmers do take some explicit account of quality in their annual purchasing of tractors. In fact, the analysis finds, that with reference to the explanatory variables considered[1], the most rational explanation of gross investment behaviour[2] is

1. Also with reference to the data limitations.
2. i.e. the explanation which leaves the least to be explained by random influences.

given when it is assumed that farmers took into account all the important quality changes over the period. Thus, the gross investment functions explaining the value of purchases, (deflated by real price), have the most significant explanatory variables and the highest total explanatory power. However, the equations explaining the demand for total horse-power offer nearly as good an explanation - with respect to annual purchases quality was closely associated with the total horse power of purchases over the period. The regressions explaining gross investment in terms of weighted numbers, a quality measure between total horse power and numbers, are not so satisfactory as the more explicit quality gross investment functions. Thus, it seems that farmers do take more account of quality in deciding the level of their annual purchases of tractors than is proposed by the simple weighting system.

The importance of existing stock to the investment decision also stands out. Thus, all the stock adjustment models have 'sensible' adjustment coefficients and indicate that there is no instantaneous adjustment of actual stock to the desired stock level as dictated by economic forces. However, only in the function explaining gross investment by deflated value, is the lagged stock variable significant. And then only is it so when it is introduced in its log form; it then is significant in exerting its expected depressing effect on gross investment. A priori, lagged stock would be expected to be more important in its log form. Then, the changes in gross investment would be dependent upon the percentage change in stock - that is upon the level of stock as well as the change in stock.

It is somewhat surprising, that only in the model where lagged stock takes account of depreciation, that lagged stock should exert a depressing effect on gross investment. Griliches (7) points out that lagged stock allowing for depreciation generates a replacement demand, whereas lagged stock with no wearing out tends to emphasise the depressing effect of stock. However, in the numbers, horsepower and weighted number models the scrapped tractor has the same measure as it did when new; whereas in the deflated value model the scrap value is very low compared to its value when new. Thus, in the latter model, actual scrapping generates little replacement demand; in the other models it generates substantial replacement demand. If scrappage is affected by economic forces, as seems likely, then this effect will be represented in the effect of lagged stock ongross investment. Thus, the lagged stock variable allowing wearing out of thetractor over time seems more realistic than that which say the tractor gives the same services until scrapped - when it suddenly becomes completely useless. In the latter case, the effect of scrappage on gross investment is overemphasised since it is determined by economic forses; whereas depreciation is determined by physical forces and attempts to measure the decline in services available from the tractor. Further evidence is provided by the stpck adjustment models; where the deflated value model could be considered the most satisfactory with regard to significance of the variables and explanatory power. Further, it has the highest adjustment coefficient suggesting that it is the most completely specified equation[1].

In the deflated value stock adjustment model the adjustment is most satisfactorily described by the model proposing a % response to a percentage disequilibrium between desired and actual stock level. Thus, absolute increases in stock tend to be at a slower rate as the level of stock rises,

1. On the basis of other empirical work using distributed lags where the most completely specified equations have the highest adjustment coefficients.

– with respect to the same absolute disequilibrium[1]. Since quality is taken explicitly into account by the stock variable then this is logical: the rising stock level tends to depress the marginal revenue product. In contrast, where stock is simply in terms of numbers, the stock adjustment model is better described by the model proposing a response in absolute terms to the absolute disequilibrium. Here, the disequilibrium is a function of quality change – tending to raise the marginal revenue product from the number of units. Thus this model is more logical than one where the actual level of stocks is important. This again is a confirmation of the importance of quality change on the demand for tractors. But also these stock adjustment functions – by deflated value and numbers – give much higher adjustment coefficients than adjustment by total horsepower or weighted numbers[2]. This contrasts with the similarity of the results from using deflated value and total horsepower dependent variables in the gross investment functions. This difference would seem to support the hypothesis that the lagged stock, by horsepower (and weighted numbers), overemphasises the importance of scrappage – because the losses in horsepower have the same measure as the gains in horsepower. This point, is probably important, in explaining why adjustment by numbers, should give a higher adjustment coefficient than by horsepower or weighted numbers. In the adjustment by numbers, although a scrapped tractor has the same weighting as a new one, the level of actual stock is partly explained by the quality of the new tractor.

Finally, as regards the importance of lagged stock, the models proposing that

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1. i.e. with respect to $S_t^* - S_{t-1}$.
2. 0.68 and 0.55 cf. 0.26 and 0.17

lagged stock affected gross investment because of the disequilibrium between it and desired stock did not turn out to be satisfactory. Thus an unrealistic answer; particularly in view of the size of the adjustment coefficient of the stock model, was derived for the percentage disequilibrium in terms of deflated value. This was probably because the model was formulated algebraically in the wrong way. Also, the replacement demand generated by losses from the U.K. fleet should have probably been a part of the proposed model. Thus no final conclusion, as to the exact way lagged stock affects gross investment, can be drawn - except that gross investment is a function of the logarithm of lagged stock, and is connected with the adjustment of actual stock toward desired stock.

The broad conclusion to be drawn from the results :. that the demand for tractors is a derived demand, adjusting the stock of tractors toward a desired stock. This desired stock level is determined by the price ratio of tractors to labour and takes account of quality changes in new tractors. The results also indicate that the adjustment process is affected by the financial variables - the % investment allowance and the rate of interest. Log of the % investment allowance is significant in explaining gross investment by deflated value and weighted numbers, and stock by deflated value. It is not quite significant in explaining gross investment by total horsepower. In terms of introduction of the 20% investment allowance the effect on sales is quite large - thus the increase from 1% to 21% in the level of investment allowances is associated with an 8% to 15% increase in sales measured in quality terms. Thus, it definitely seems to have been an incentive to investment; particularly to replacement of a tractor by one of a higher quality, since it does not influence gross investment by numbers.

The exact importance of the interest rate variable - was hard to analyse because of its high correlation with other explanatory variables. However, it usually had the expected sign; it was significant in explaining gross investment by horsepower and not quite significnat in explaining gross investment by deflated value. The significance of its coefficients was improved by a linear formulation - as opposed to log-log or semilog formulations. This indicates that changes in gross investment, as measured in qulity terms, are associated more with the size and direction of the absolute change in bank rate than with % change. This indicates that the variable is acting more as a financial constraint - associated with the availability of credit, rather than being important through changing the discount rate. Further evidence is provided for this hypothesis by the fact that it is not significant in affecting the stock equation by total horsepower; therefore it is only relevant to the level of gross investment not to the desired stock level[1] - which is a function of economic forces.

The other variables which have some influence on the investment decision, depending on the formulation of the function, are the price of tractors relative to the price of crops, farm size, the level of advertising expenditure and the relative prices of large and small tractors. The variable, price of tractors relative to the lagged price of crops, is only significant in the function with the dependent variable in terms of deflated value and the price of tractors expressed in real terms. In explaining gross investment, it is dominated by the other price ratio, real price of tractors relative to labour earnings with which it has a very high intercorrelation, and is only significant when the latter is omitted. In the stock adjustment model it is significant even when both price ratios are included. Its influence is not very important

1. Though it does have a high simple correlation coefficient with lagged stock by horse-power and there may be a mutlicollinearity problem.

since the estimated elasticities are low[1]. Thus it does mean that expectations (as measured by the lagged crop price) have some importance; but only if expressed relative to the real price of tractors and then they only stimulate a small response. They do not have the important influence on the investment decision that has been emphasised by investment studies of U.S. agriculture. This may be a consequence of the effects of the U.K. price guarantee system - thus, if price expectations are stable and crop prices are not expected to alter, then expectations will have little influence on the demand for inputs.

Farm size, as represented by the proxy variable % of farms of more than 300 acres, is an influence on investment where the dependent variable is expressed in quality terms. It appears with a positive coefficient, although not always significant, indicating that increased farm size increases the per acre demand for tractor services and appears to be a trend element in explaining demand. The variable, level of total advertising expenditure, was only significant in explaining gross investment by weighted numbers and then only when the % investment allowance variable was excluded. However, it does indicate, that advertising could have influenced the total demand; by encouraging a higher quality model to be bought, than would be dictated by other influences. Because it is only significant in explaining gross investment by weighted numbers, it seems likely, that it has affected demand through the selling of new tractor models of much higher horse-power than the old models. Thus firms have diversified the range of models available; at the same time advertising has promoted sales of the larger models. The influence of advertising expenditure - on the other dependent variables is not easy to analyse because the variable is highly correlated with other explanatory variables. However, it does appear that it has had a negligible influence on total demand; hence it seems that the total advertising, by the tractor firms,

1. -0.65 and -0.25 with respect to gross investment and actual stocks respectively.

is mostly competitive - in the sense of promotion of brand images, rather than toward increasing the total market. But, advertising may play some part in the selling of new models over and above the level required by economic forces; this may particularly be by encouraging replacement earlier than would otherwise occur. Finally, the ratio of the price of large tractors to the price of small tractors is of some importance in explaining gross investment by weighted numbers. As would be expected, as the relative price of small tractors increases so it has encouraged the trend toward larger tractors.

Several variables were found notto influence the investment in tractors over the period. In the case of lagged profits[1] this seemed surprising from a priori reasoning - particularly as although non-significant, lagged profits always appear witha negative coefficient. It seems reasonable to suppose that this is a result of looking at disaggregated investment. Thus tractors are a fairly basic input, the required level of stock (in terms of available services) must be maintained despite the level of past profit. Thus, it might be that investment in other farm machinary occurs after years of good profits in a cyclical manner whereas investment in tractors is not subject to this liquidity cycle. It would need a multiequation model to investigate this hypothesis properly. In fact, it appears that as far as tractor investment is concerned, external credit is more important than internal credit since the interest rate charged by banks to farmers does have some importance. Lagged profits have also been used as a proxy variable for expectations; as indicated by the non-significance of lagged crop prices, expectations of the future do not seem to be very important (as far as they are represented by these variables).

The other variables that were not important were all technical variables. It is interesting that there was no significant supply shortage in 1948, 1964

1. As represented by lagged U.K. net farm income.

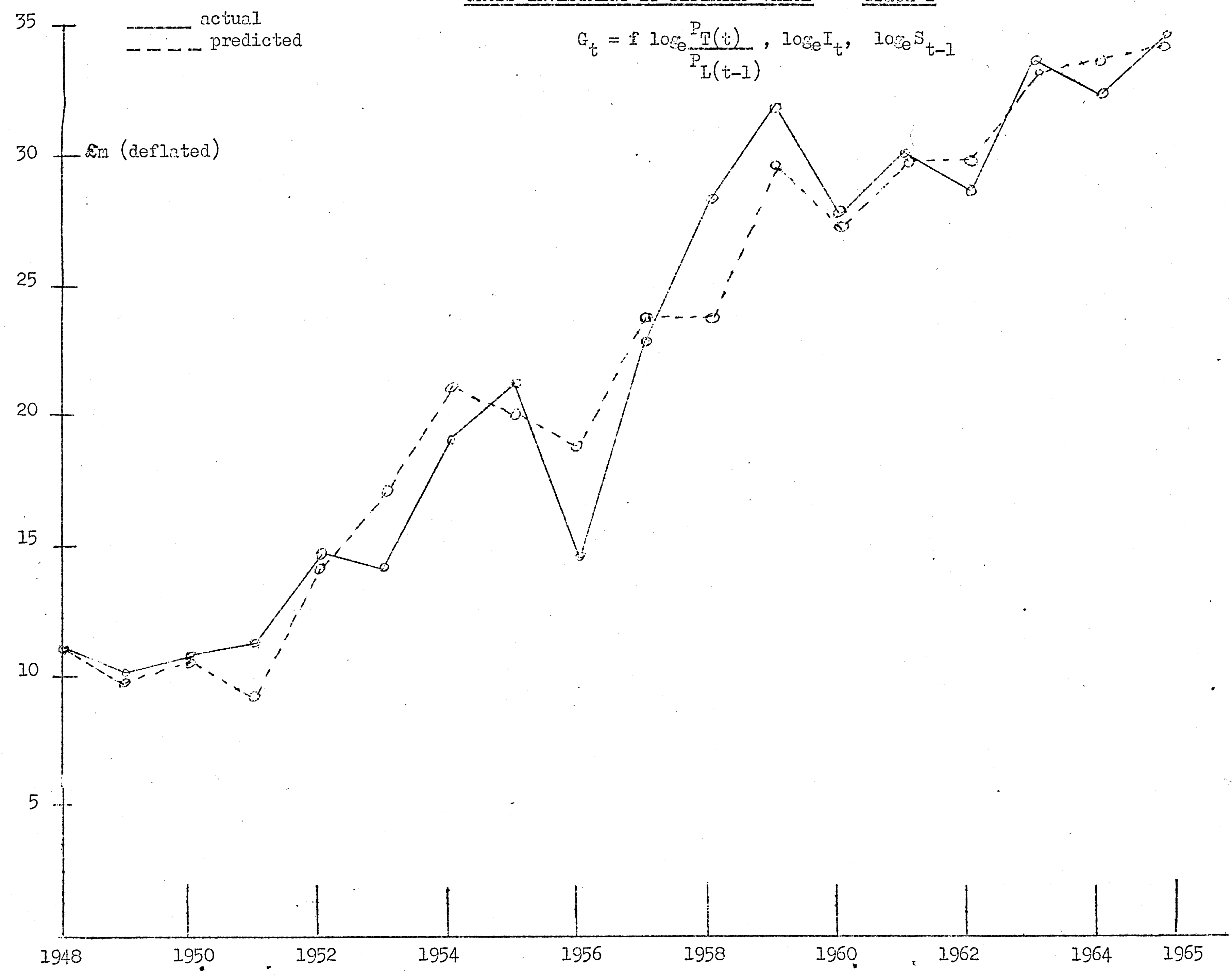
and 1965 as tested by the dummy supply variable. In fact, looking at the residuals from the gross investment regression equations for those years only 1964 is negative. This adds support to the hypothesis that a simultaneous model with respect to export/home allocation was not needed. This is provided, that the correct years were specified as being years of supply difficulty. It is interesting to note that in the three years specified tractor imports were up quite markedly as compared to other years.

There was no evidence to support the hypothesis that autumn weather affected total demand the following year: if it has an influence it must therefore be in the very short term. There was also no evidence to suggest that the level of used exports affects the time of replacement within the home fleet. Finally, there was no evidence to support accelerator type reasoning through the lagged crop acreage variable.

Finally, with regard to prediction of gross investment from the models, true prediction - prediction outside the sample period - has not been made. However, to judge by predictive ability <u>inside</u> the sample period, then it appears that the best predictions would be given by the gross investment equations in terms of deflated value. Thus graphs I and II compare predicted and actual values of gross investment in terms of deflated value and numbers for years within the sample period. In terms of deflated value prediction shows roughly the same fluctuations as actual values. For sales by numbers however, a fairly constant level is predicted whereas the actual level was subject to many fluctuations. Prediction of total horse-power of sales within the sample period, in terms of the ratio of the price of tractor horse-power to labour earnings, the bank rate plus 1% and lagged stock, shows nearly as good a prediction as the deflated value model. Prediction in terms of weighted numbers is somewhat better than by number alone but not as accurate as the two more explicit quality measures. The one year that is poorly explained by all

GROSS INVESTMENT BY DEFLATED VALUE   Graph I

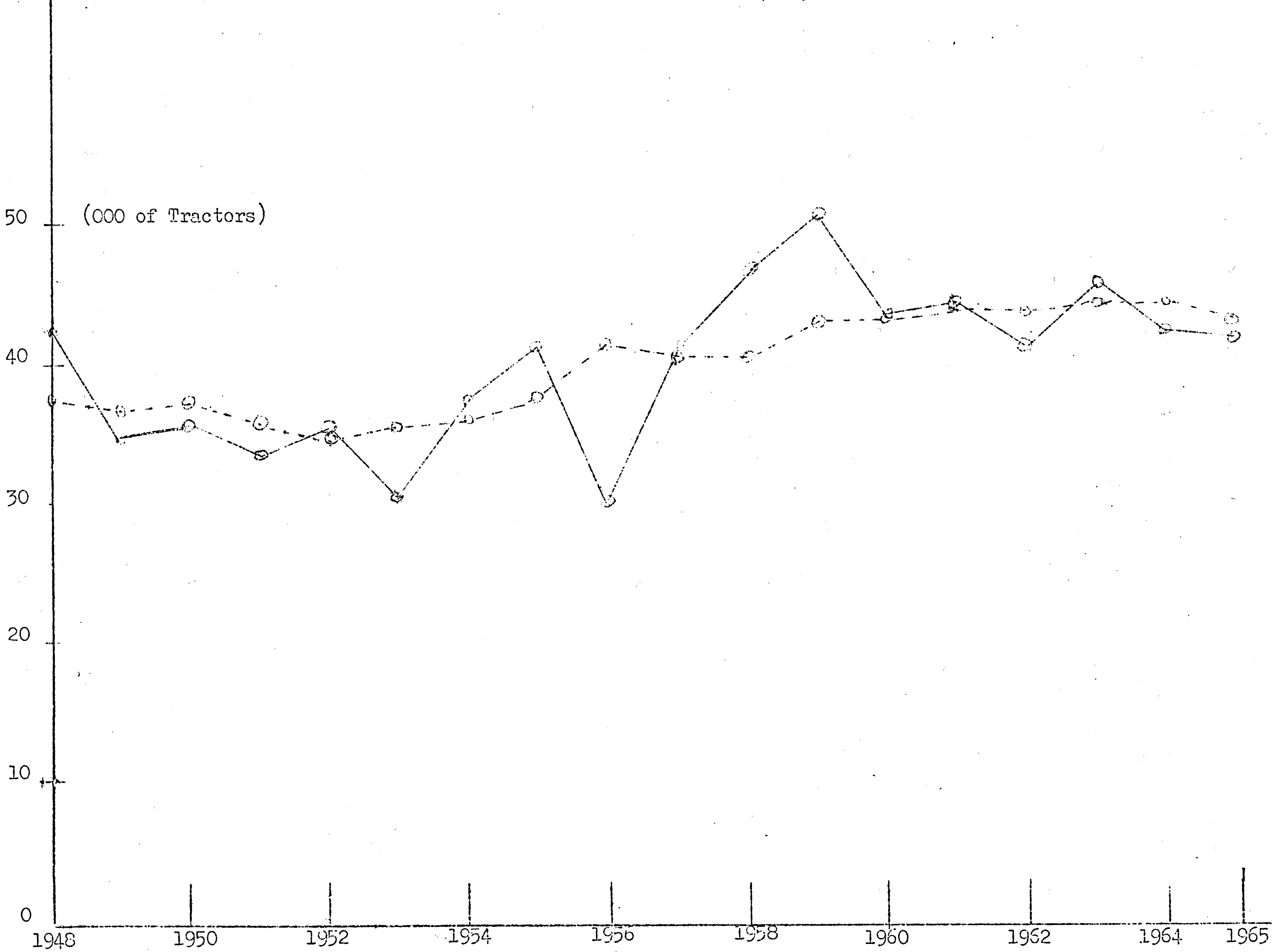
$$G_t = f \log_e \frac{P_{T(t)}}{P_{L(t-1)}}, \log_e I_t, \log_e S_{t-1}$$



GROSS INVESTMENT BY NUMBERS — Graph II

$$G_t = f\left(\frac{P_T(t)}{P_L(t-1)},\ Q_t\right)$$

——— Actual
- - - Predicted



regressions is 1956; the residuals seem to indicate that there was a supply shortage in that year. Prediction outside the sample period can be made for one year in advance, since the explanatory variables are either lagged or set at the beginning of the period.[1] Some difficulty would arise with the deflated value model because the constant quality price index is relevant to the sample period. This would need extending and perhaps a different specification of the quantitative aspects would need to be made to make it more relevant to the year of prediction.

In summary, the results indicate that the demand for new wheeled farm tractors, in the U.K., represents an adjustment toward a desired stock level. This desired stock level is primarily determined by the price ratio of tractors to labour earnings and is increasing in a process of capital deepening on farms. The results also show the importance of taking quality change of the capital input into account; the more completely does the dependent variable express quality change the more can gross investment be explained. However, in this respect quality is very largely associated with total horsepower. The financial variables - the level of the % investment allowance and interest rate charged to farmers by banks - affect the level of demand and the adjustment process. The investment allowance was introduced with the purpose of encouraging higher investment in machinery and it has had the desired effect; in fact the regressions pick out quite a marked response by farmers to the introduction of the 20% allowance. The affect appears to have worked by encouraging earlier replacement and replacement by a higher quality tractor. Interest rate appears to have affected gross investment through some association with credit availability, rather than acting as the relevant discount rate to expected earnings from tractors. In fact, the expectation of future earnings from tractors appear

1. Except that the tractor prices used are September prices - however January prices may be used as an approximation.

to have played only a minor role in determining the level of tractor demand.

As far as the gross investment functions are concerned, the regressions explaining gross investment by deflated value are the most relevant to the demand for tractors over the period. The indicated elasticities of gross investment by deflated value at the mean of gross investment are:-

1)	with respect to $\frac{\text{'real' price of tractors(t)}}{\text{Labour earnings (t-1)}}$	-2.52
2)	with respect to % investment allowance (t)	+0.05[1]
3)	with respect to lagged stock (t-1)	-1.24

The gross investment functions explaining gross investment by total horse-power indicate a somewhat lower elasticity, at the means, with respect to the relevant price ratio of tractors to labour earnings[2] : -1.50. The interest rate variable is significant in this regression and indicates an elasticity of -0.36 at the means of gross investment and the interest rate. Both the price elasticities do imply that large fluctuations in gross investment occur in response to changes in these price ratios.

In contrast, the stock demand elasticities are much lower, implying that the effect on agricultural output, of a change in the relative price of inputs, is small in the short run. Accepting the conclusion that the stock adjustment function in terms of deflated value is the most satisfactory, both from taking account of quality and because it accounts for lagged stock more correctly, then the follwoing elasticities are obtained:-

1. The elasticity is low partly because we are feferring to a % of of a %; The effect of % investment allowance is quite marked. Thus the introduction of the 20% investment allowance is associated with an increas in sales of around £3m. (deflated).
2. Average price per tractor h.p.(t)/ labour earniggs (t-1).

1)	With respect to $\frac{\text{'Real' price of tractors (t)}}{\text{Labour earnings (t-1)}}$	-0.66
2)	With respect to $\frac{\text{'Real' price of tractors (t)}}{\text{Price of crop (t-1)}}$	-0.24
3)	With respect to % Investment allowance (t)	+0.01

The adjustment coefficient for this function was high: 0.68, indicating that farmers adjust stock quite quickly to changes in the above variables. The resulting desired stock elasticities are -0.97 with respect to real price of tractors (t) compared to labour earnings (t-1) and -0.35 with respect to real price of tractors (t) compared to price of crops (t-1). Hence, even in the long run, there is still a fairly limited response to price changes in relative inputs and output. The adjustment coefficient estimated from stock adjustment by numbers was also high (0.55), here the problem of overweighting scrappage was dealt with more satisfactorily than in the total horsepower or weighted number stock adjustment functions.

Some influence of the market structure on total demand is seen via total press advertising expenditure. This seems to have some effect on increasing the demand for higher quality tractors beyond that dictated by other forces. In particular, this could work in years when new models of higher horsepower are introduced. Finally, with regard to future demand, the actual numbers of units demanded seems likely to remain around the present level or even begin to fall off. However in terms of quality, demand is likely to increase if wage earnings increase faster than real tractor prices. Most of the quality demand is associated with demand for higher tractor horsepower.

The change in government investment allowance to the new cash grant system is likely to reduce demand slightly since the 10% cash grant is less of a financial inducement than 30% of cost to be offset against tax at the standard rate. Although against this, there is the argument that more farmers will apply for the cash grant because it is easier to assess. It is interesting that regression analysis finds % investment allowances to be important in this case; survey analysis of the manufacturing sector in the U.K. has tended to find them unimportant. Finally, all the regressions estimated may be considered to be structural only under the present governmental support system to agriculture. If this was to be radically changed then expectations might play a much larger part in explaining tractor demand.

Appendix A - Data Sources

(A) Personal correspondence with the Statistics Division, Ministry of Transport.

(B) Annual data on shipments provided by:-

i) Ford Motor Co. Ltd., Basildon, Essex.

ii) International Harvester Co. of Great Britain, London.

iii) David Brown Tractor Co. Ltd., Meltham, Yorks.

iv) Perkins Engines Ltd., Peterborough.

v) Massey-Ferguson (U.K.) Ltd., Coventry.

vi) The British Motor Corporation Ltd., Longbridge, Birmingham.

vii) Allis Chalmers Tractors Ltd., Essendine, Lincs.

(C) Board of Trade; Accounts relating to the Trade and Navigation of the United Kingdom December issues, 1948-1964.

and

Board of Trade, The Overseas Trading Account of the U.K., December issue, 1965.

(D) Farmer and Stockbreeder Publications Ltd., Farmer and Stockbreeder Year Book and Desk Diary annual 1948-1966, reference section.

(E) Agricultural Machinery and Tractor Dealers Association Limited, 'Blue Book' 1965.

(F) Stone and Cox; "Motor Specifications and Prices", annual, 1948-1965.

(G) Statistical Dept., Society of Motor Manufacturers and Traders; Motor Industry of Great Britain, annual, 1948-1965.

(H) Earnings of agricultural workers adjusted to include national insurance payments by employers; confidential data from the Ministry of Agriculture, Fisheries and Food - Wage and Employment Enquiry.

(I) Central Statistical Office; Monthly Digest of Statistics, January issues, 1949-1966.

(J) Central Statistical Office; "Annual Abstract of Statistics", annual, 1948-1965.

(K) London and Cambridge Economic Service; "Key Statistics of the British Economy 1900-1964"

(L) Ministry of Agriculture, Fisheries and Food; "Agricultural Statistics : England and Wales", annual, 1947/48-1960/61.

(M) Ministry of Agriculture, Fisheries and Food; "Agricultural Statistics : United Kingdom", annual, 1946/47-1963/64.

and

Ministry of Agriculture, Fisheries and Food; Agricultural Price Indices No. 55, June/July 1966.

(N) Meteorological Office; Monthly Weather Report (Met. O.763); September, October, November and December; 1947-1964.

(O) School of Agriculture, Cambridge; A Scale of Available Working Days; obtained by personal correspondence with N.A.A.S., Leeds.

(P) Personal correspondence with
Legion Publishing Co. Ltd.,
Breams Buildings,
London E.C.4

Appendix B

1) Data relevant to the Dependent Variable

YEAR	Number of New Tractors subject to Hire Purchase Agreements	Estimated Average Horse-power of Tractors sold	% of Tractors sold with Diesel Engines	Estimated Value of Gross Investment in current prices (£m)	Estimated Value of the End of year Stock of Tractors in current prices (£m)
1948	n.a.	24.1	4.5	14.065	45.06
1949	n.a.	24.4	4.9	12.448	50.75
1950	5,072	24.2	6.7	13.261	54.63
1951	4,322	27.7	14.6	13.818	58.75
1952	3,837	29.8	42.4	17.016	65.63
1953	4,467	30.8	73.1	15.550	70.27
1954	4,684	31.1	82.4	20.239	79.10
1955	5,505	31.6	88.7	22.369	86.54
1956	3,951	32.3	94.1	15.477	85.78
1957	5,428	36.0	95.1	23.474	94.61
1958	5,922	35.8	97.4	28.887	105.54
1959	6,472	39.6	97.7	31.140	116.63
1960	5,022	40.4	99.0	27.271	121.47
1961	5,277	42.1	99.3	29.565	127.15
1962	4,151	43.5	99.6	28.753	131.36
1963	4,288	44.8	100.0	33.365	139.00
1964	5,510	45.1	100.0	32.868	144.79
1965	4,607	49.5	100.0	36.778	152.32

n.a. not available.

2) Calculated series of the Explanatory Variables

YEAR	Index of the Average Price of Tractors (t) ÷ Index of Labour earnings (t-1)	Index of the Real Price of Tractors (t) ÷ Index of Labour earnings (t-1)	Index of the Average Price per Tractor h.p.(t) ÷ Index of Labour earnings (t-1)	Weighted Bank Rate of Interest	% of Farms in the U.K. of > 300 acres
1948	103.9	244.7	163.7	2.00	*15.23%
1949	108.1	226.9	167.6	2.00	15.21
1950	106.9	208.5	167.3	2.00	15.27
1951	114.8	205.4	157.4	2.14	15.31
1952	122.3	180.2	155.9	3.70	15.39
1953	122.1	157.6	150.1	3.85	15.48
1954	121.6	145.9	148.2	3.19	15.50
1955	117.1	139.6	130.2	4.30	15.68
1956	103.2	127.8	121.0	5.37	15.82
1957	107.1	116.6	112.6	5.59	15.97
1958	109.7	109.9	109.7	5.40	16.58
1959	102.9	99.7	98.4	4.00	16.78
1960	102.1	96.7	95.8	5.35	16.96
1961	101.4	90.6	91.3	5.67	17.23
1962	101.5	89.1	88.3	4.90	17.33
1963	100.6	83.6	85.1	4.00	17.43
1964	101.3	80.3	84.0	5.00	17.50
1965	107.5	78.7	82.2	6.42	**

* The % in 1947 was 15.17%

** Not needed for the regressions

2) Continued

YEAR	Index of the Average Price of Tractors (t) ÷ Index of the Price of Crops (t-1)	Index of the Real Price of Tractors (t) ÷ Index of the Price of Crops (t-1)	Index of the Price per Tractor h.p.(t) ÷ Index of the Price of Crops (t-1)	'Real' U.K. Net Farm Income (t) (£m)	Weighted U.K. Net Farm Income $\left(\Pi_t = \frac{3\Pi_t + 2\Pi_{t-1} + \Pi_{t-2}}{6}\right)$ (£m)
1947	*	*	*	373.0	360.9
1948	76.5	180.3	120.6	421.4	392.5
1949	74.8	156.9	115.9	433.1	419.3
1950	78.3	158.4	122.6	356.8	388.2
1951	82.1	147.0	112.6	380.0	381.1
1952	80.5	118.3	102.4	372.0	372.1
1953	90.5	116.8	111.3	383.6	379.1
1954	95.7	114.8	116.6	346.1	362.9
1955	97.9	116.7	117.5	376.1	367.4
1956	88.4	109.5	103.7	351.0	358.6
1957	93.5	101.9	98.4	376.8	368.1
1958	108.5	108.7	114.8	333.0	350.6
1959	88.7	86.0	84.8	360.6	354.1
1960	100.0	94.8	93.8	385.9	368.6
1961	121.4	108.6	109.3	405.7	391.6
1962	126.5	111.0	110.1	422.8	411.0
1963	116.8	97.1	98.8	378.0	397.3
1964	126.9	100.5	105.1	421.4	407.2
1965	157.3	115.2	120.3	*	*

* Not needed for the regressions.

2) Continued

Exports of Used Tractors

Year	1952	1953	1954	1955	1956
Number	800	2,400	2,249	2,190	3,111
Value (£m current prices)	0.150	0.800	0.764	0.614	0.774

Year	1957	1958	1959	1960	1961
Number	3,416	4,937	6,233	8,308	9,915
Value (£m current prices)	0.869	1.021	1.414	2.043	2.846

Year	1962	1963	1964	1965
Number	10,223	10,866	11,967	10,386
Value (£m current prices)	2.972	2.804	3.633	3.207

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