MANCHES

WP 88/02

Manchester Working Papers in Agricultural Economics

A Total Factor Productivity Index for U.K. Agriculture 1967-87

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(WP 88/02)

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1) INTRODUCTION

The objective of this paper is to derive a total factor productivity (TFP) index for U.K. agriculture and to progress as far as possible towards constructing a production data set. Conceptual issues are stressed rather than the well documented technical aspects of productivity measurement and emphasis is placed on the value judgements involved in data selection and manipulation. We hope this paper will be treated as work in progress and will attract constructive comments.

The next section reviews the literature. Then section three considers alternative derivations of TFP indices before section four explains the practical problems involved in producing a TFP for UK agriculture from national income accounting data. Section five explains index number theory and particularly the derivation of the Tornqvist-Theil approximation of the Divisia index. Section six applies this methodology to the UK data, explains the problems encountered (and their solutions) and reports the results. In lieu of a conclusion, we offer some comments on the resultant indices and suggest how they might be used in future work.

2) REVIEW OF THE LITERATURE

Regrettably, official government agricultural statistics for UK agriculture do not include a total factor productivity (TFP) index, although a labour productivity series has been published in the Annual Agricultural Review since 1971. MAFF has in the past produced TFP indices sporadically (CSO, 1961, 1969) but only the years from 1949-67 are covered. Attempts to correct this deficiency have been made by Whittaker (1983), Godden (1985) and Doyle and Ridout (1985), but none of these indices extends past 1981. Whittaker is by far the best documented of the three attempts and for this reason provides the soundest foundation on which to build. The results of Whittaker (1983) are published in Rayner, Whittaker and Ingersent (1986), which extends the analysis by using an input output framework to study productivity in the vertically integrated agricultural sector. This work is a shortened and modified version of Rayner,

[1]. Paul Bottomley is a graduate student at Manchester Business School. Adam Ozanne is a graduate student in the Department of Agricultural Economics, Univerity of Manchester and Colin Thirtle is a Lecturer in the same department. Colin Thirtle is responsible for sections 1-4 of this paper. Adam Ozanne is responsible for the theoretical background, presented in section 5. Paul Bottomley performed the calculations, which he explains in section 6. We would like to thank Paul Allanson and Michael Burton of the University of Manchester and Julie Whittaker of the University of Exeter, for discussions, ideas and generosity in making available earlier work, which made this study possible.

Whittaker and Ingersent (1985).

Apart from these few empirical studies, there are many papers covering the conceptual and theoretical issues involved in the construction of such indices. These will not be reviewed here since there has been little change since the discussion in Thirtle (1986).[2] However, it is worth noting that other countries do have well developed TFP indices. For example, the USDA (annual publication) publishes a TFP index that begins in 1910, land and labour productivity indices, by enterprise group and for each of the ten farm production regions, dating back to 1939 and TFP indices by region, also from 1939. Criticisms of the USDA TFP indices (Christensen 1976, USDA, 1980) have led Ball (1984, 1985) to produce a Tornqvist-Theil TFP index and Evenson, Landau and Ballou (1987) to calculate TFP indices by state, rather than by region.

3) DERIVING TFP INDICES

Consider a production or agggregator[3] function with m outputs and n inputs,

$$F(y_i : x_j : x_k) = 0, \quad i = 1, ..., m \quad j = 1, ..., p \quad k = 1, ..., q \qquad (1)$$

where p + q = n and : denotes weak separability.[4] If the set of m outputs are separable from the input sets (x_j, x_k), then the m outputs can be aggregated to a single output. Similarly, if the p inputs in set x_j are weakly separable from the outputs and the remaining inputs, in set x_k, then they can be reduced to a single aggregate input. The ratio of the single output aggregate to the single input aggregate of the set x_j, may be called a total factor productivity index, though exclusion of the input set x_k makes it clear that TFP is a misnomer. The type of index will be determined by the choice of aggregate function. For

[2]. One major survey of the area has appeared since (Link, 1987).

[3]. This terminology, used by Diewert (1978), and others, is useful in that it makes explicit the fact that aggregation and production function estimation are, in some sense, the same process.

[4]. Functional separability requires that,

$$\frac{\partial \left(\frac{F_i}{F_j}\right)}{\partial (X_k)} = 0 \text{ for all } i, j \subset N \text{ and } k \not\subset N$$

where, for this two group case, N denotes either group of factors, and F_i,F_j are the marginal products of X^i and X_j. Hence, separability requires that the rate of substitution between two factors in one group should be independent of the level of factor inputs in the other group.

TFP is a misnomer. The type of index will be determined by the choice of aggregate function. For example, this is the rationale followed in Thirtle and Bottomley (1988), in which the geometric index (exact for the Cobb Douglas production function), is used to demonstrate the derivation of the TFP index.

Now, if the p inputs in set x_j, are the usual set of conventional inputs and the q inputs in set x_k are the set of non conventional inputs (R & D, extension efforts, farmer education and the weather), changes in which are assumed to explain changes in TFP, then the logic of the two-stage procedure for explaining productivity change is made explicit. Particularly, there is no good reason to assume that the outputs and the two input groups will be separable[5], as is required for aggregation.

The relationships above define the production function approach to deriving a TFP, which is perhaps the most obvious and intuitively appealing method. However, Evenson, Landau and Ballou (1987) show that there are basically two formal procedures for deriving TFP indices. Firstly, as discussed above, a TFP can be derived from the production function, or exploiting duality from the cost function associated with the productive function, or from the output supply and input demand functions derived from the associated profit function. Alternatively, a TFP can be derived from <u>economic accounting relationships</u>. Evenson, Landau and Ballou show that if the aggregator function in the production function (or the dual relationships) derivation is the translog, which is a flexible functional form and acts as a second order approximation of any unknown production function, then the Divisia index (which is exact and superlative for the translog) derived from the production framework will be the same as the Divisia index form resulting from the accouting derivation.

This coincidence of outcomes is convenient, since in the U.K. there is no consistent production function data set, corresponding, for example, to the material in the USDA's <u>Changes in Farm Production and Efficiency</u>. Production function studies of UK agriculture have thus rested on data collected in a piecemeal fashion, though we do not doubt the knowledge, judgement and ingenuity of some practitioners (see, for instance, Burrell, 1988). However, given that even the UK produces national income accounts and that these accounts include the agricultural sector, there is an alternative. The (presumably consistent) accounting data published in MAFF, Departmental Net Income Calculation (DNIC), Annual Review[6]

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[5]. If they are not, this factor would mitigate in favour of a single stage estimation of the production function, including both conventional and non-conventional inputs, rather than first constructing a TFP index. There do seem to be some interesting developments in this area (see, for example Basmann, Hayes and Slottje (1987) and Baltagi and Griffin (1988). Evenson, Landau and Ballou call the single stage method "integrated estimation" and offer a discussion of its advantages and disadvantages relative to the two stage procedure.

[6]. The material appearing in the Annual Review of Agriculture (HMSO, various years) White Paper also has this as a basic source.

(various issues), which is reprinted in the CSO's Annual Abstract of Statistics (various years), provides a data set from which production function data or TFP's could be derived. Indeed, these data, which are agriculture's contribution to the National Income accounts, are used in Whittaker (1983).

At the practical level, there are numerous value judgements involved in converting the accounting data into a production framework, which are not addressed by Evenson, Landau and Ballou (1987). The conversion from an accounting framework to a TFP index is easier than constructing a production data set. This is true, since the level of aggregation is higher. Troublesome items need only be allocated to the output or input aggregates, rather than to individual components of those aggregates. Even so, we have gone as far as possible in the direction of constructing meaningful input and output variables, since in the longer term we would want to estimate production functions.

4) FROM ACCOUNTING TO PRODUCTION DATA

This section begins with a general discussion of the concepts involved in the DNIC accounts and the problems that arise in converting these data to a data set that is compatible with neo-classical production economics. This is followed by an item-by-item description of the way in which the output and input aggregates for the TFP index are constructed from the DNIC tables.

(a) BASIC CONCEPTS AND PROBLEMS

1) The National Farm

The DNIC accounts are explained in HMSO (1973, 1981) and MAFF (1984), which provides a reasonably detailed description of each item in the accounts. The crucial accounting convention employed is that of the national farm, in which "all producer units are regarded as forming a single national farm and only transactions involving movements across the national farm boundary are quantified and valued" (MAFF, 1984, p.1). The national farm concept, as stated above, is clearly quite a suitable basis for the estimation of agricultural production relationships.

2) Final and Intermediate Product

Unfortunately, the reality is less good than the claim, since the accounts are for the calendar year, and items that cross this time boundary also have to be quantified and valued. These items include farm produced capital goods and changes in year-end stocks of intermediate inputs such as feed grains. Thus, if output is to equal income, which must also equal expenditure, capital goods produced, but not used, in the current period, must be included in final output, along with potatoes and milk, although they do not cross the farm boundary. Capital goods produced and used up in the current period are treated as an intermediate product and are not included in final output. Capital goods produced, but not used in the current period are added to the capital stock of the next period and the user costs for that period will hence be based on a stock that includes any such additions.

Switching to the concepts and language of production economics, the consumer goods sector uses the output of the capital goods sector as an input, but a production function should not be fitted to a "sector" that is producing as outputs some of its own future inputs. At least three solutions are possible. Firstly, the agricultural sector could be regarded as a consumer goods sector and the capital good outputs deliberately excluded. To the extent that labour and other inputs may produce more capital goods relative to consumer goods in one period, relative to another, factor productivities would be distorted and the production relationship may be a poor fit. Secondly, the hybrid nature of the agricultural sector could be admitted, and the capital items included in output. This is at odds with the neoclassical model, but more in keeping with commonsense. Thirdly, the technically correct solution would be to model agriculture as a two stage technology or sequential production process in which primary inputs are used to produce intermediate inputs that are then used to produce final output. This solution adds to the level of difficulty and will not be attempted at present, but is clearly worth considering since capital produced within the agricultural sector is only a part of this problem, which we now consider further.

3) Two Stage Production in Agriculture

The second solution suggested above corresponds to the treatment of feed grain (and seed) in the DNIC calculations. On farm consumption of farm produced feed grain is treated as an intermediate input, so only purchased feed and the change in stocks over the period enters the calculations. Similarly, the research production process results in an intermediate input called new technology, that can be viewed as an input in the production of final output. Thus, for farm produced capital, clear intermediate inputs such as feed and even for technology, a strong case can be made for a sequential, two stage model, perhaps of the type recently investigated by Pollak and Wales (1987).

4) Capital Items

As suggested above, stocks and work-in-progress enter the accounts only as the end of period change in levels. Capital items present the usual stock-flow problem. We have tried to stay close to the usual techniques for converting stocks into input flows, by attempting to get at the opportunity cost (user cost is a frequently used term) of capital services. The flow concept is constructed of interest, depreciation and any other charges, such as licence fees on vehicles.

5) Output Valuation

For U.K. purposes, output is valued at factor cost, which is again a suitable basis for production economics, in that the objective is to model farmer decision making and quantities and prices should be those applying to farmers. That is, input prices should be adjusted to allow for subsidies and any indirect taxes such as licence fees, in order that prices should reflect the opportunity cost of input usage. Similarly, output prices should be market prices, plus any grants and subsidies, minus any taxes or levies on output.

Unfortunately, these calculations are complicated by the DNIC procedures, since "any subsidies paid on input items are included under production grants rather than as a discount on the input side" (HMSO, 1981, p.94). Also, while some subsidies and taxes are enterprise or input-specific, others, like aid to Less Favoured Areas, are not. This problem is apparent in the itemised calculations of inputs and outputs that follow later.

6) Imputation

In general, the problem of imputing values to non-market goods and services is solved by assigning to them the value of identical or similar goods and services that do pass through markets (Dernberg and McDougall, 1968). Thus, in national income accounts owner-occupied housing is imputed a rental value. For UK agriculture, "the agricultural account had for many years been compiled on the assumption that the national farm was wholly tenanted with an imputed rent being attributable to the owner occupied sector" (HMSO, 1981, p.97). In 1980, the rent calculation was revised to reflect only rent actually paid for tenanted land, which had by then fallen to only 40% of the total. However, if land is to enter the calculations at something like its opportunity cost, it seems sensible to use the pre-1980 method and to continue to impute rent to the entire land area of the national farm.

7) Crop years and calendar years

Until 1978, accounts were conducted on a June/May crop year basis, but since then the accounting period has been changed to calendar years, to be consistent with EC practices. Crop year calculations are no longer available and since the calendar year series has been estimated back to 1967, this basis is used here. This has its costs, since "it is more difficult to study trends for individual commodities since the effect of changes in prices and levels of production clearly tend to follow a crop year pattern" (HMSO, 1981, p.96).

(b) CALCULATION OF INDIVIDUAL OUTPUTS AND INPUTS

The basic principles outlined above are now applied to the calculation of individual inputs and outputs. The procedures followed here is based largely on the variable definitions given in MAFF (1984) and in the DNIC. It should be said that there are two parts to any index. Firstly, the output and input series themselves, are taken from the constant price series published in Appendix B of the DNIC Blue Books. These are not deflated by the base year prices, since a multiplicative constant does not affect the data as used for the current purpose. For a production data set, deflation may be necessary, at some future time. Secondly, each output and input series must be appropriately weighted. In this case the weights are shares in the value of output or input, calculated using the current price data in Table 1 of the DNIC Blue Books. The rationale for this procedure and further explanation is given in section five, which follows next. The numbers appended to variables are those used in Table 1 of the DNIC Blue Books. Subscripts, such as t and t-1 refer to calendar years, when these are applicable.

OUTPUTS

1) $(\text{TOTAL FARM CROPS})_t = (\text{TOTAL FARM CROPS})_t$

$+ (\text{OUTPUT STOCKS})_t - (\text{OUTPUT STOCKS})_{t-1} - \underset{\text{(Intermediate)}}{\text{FEED AND SEED)}}$

+ (COMPENSATION PAYMENTS) (i.e. PMB + del Pars)

Total farm crops is item (1). Output stocks are given under item (9). Feed and seed appear as item (12), Total Intermediate Output and are subtracted from Gross Output (item 11) to give Final Output (item 13). These items are defined to be "sales included in Output but subsequently repurchased and so re-appearing in Input" (DNIC, Table I). If this statement can be interpreted as it is written, these items could be included in both output and input accounts or subtracted from both. Here, we have subtracted intermediate feed and seed from gross output (to give final output (item 13) and have also subtracted these items from purchased feed and seed on the input side, where the items appear in the Table as the difference between Gross Input (item 16) and Net Input (item 17). Compensation payments matter only for the share weights. PMB compensation payments and deficiency payments on retentions (both under item 6) were taken to be specific to crop output and were included here.

2) (TOTAL HORTICULTURE)

Used as given. Stocks of apples and pears are unfortunately included with cereals and potatoes, and so represent an error in equation (1).

3) (TOTAL LIVESTOCK) = (TOTAL LIVESTOCK) + (WORK IN PROGRESS)

+ (BREEDING LIVESTOCK) + (PRODUCTION GRANTS(OTHER)) +

(COMPENSATION PAYMENTS)(i.e. ANNUAL DISEASE AND EWE PREMIUMS ETC.)

Work in progress (livestock) (item 9) is non breeding animals and all poultry. Breeding livestock capital formation is investment or disinvestment in cattle, sheep, pigs and horses.

Production Grants (other) is item (7) and as Table 2 in the DNIC shows, these grants all relate to animals, except for a very minor horticulture item. These grants and the remaining elements of Compensation Payments (item 6). Animal Disease Compensation, Brucellosis Incentive Payments, Annual

Ewe Premium, CAP Support and Other Miscellaneous Receipts) were included in calculating the weights for the livestock series.

4) (LIVESTOCK PRODUCTS)

Used as given.

5) OWN ACCOUNT CAPITAL FORMATION (OTHER ASSETS)

Fixed assets, pig and poultry housing, hedges, gates, walls and glasshouses. Hard to allocate to any one enterprise.

SUMMARY

The variables above include all the items listed in the DNIC, Table I that are aggregated to give the figures for Final Output (item 13), except fertilizer and lime production grants (item 7) which we have included on the input side (see paragraph 5 above, in this section).

INPUTS

(FEED) = (FEEDINGSTUFFS (PURCHASES)) - (INTERMEDIATE OUTPUT:FEED)

- (CHANGE IN STOCK (PURCHASED FEEDINGSTUFFS))

For production data, there is a case to be made for leaving intermediate outputs and inputs in the calculations, but it can't affect TFP calculations.

(SEED) = (PURCHASED SEED) - (INTERMEDIATE OUTPUT:SEED)

Again, could include intermediate inputs.

(LIVESTOCK)(IMPORTED AND INTER-FARM EXPENSES)

This variable is only livestock purchases and the costs of moving livestock around the country. It is not in any sense a substitute for including herds as a capital stock in production function calculations, which was the approach used by Godden (1985), for example. Again, further thought is required on the livestock enterprise if a production data set is to be produced, but the current treatment may be satisfactory for a TFP index.

(FERTILIZER) = (FERTILIZER AND LIME ex subsidy)

- (PRODUCTION GRANTS:FERTILIZER AND LIME) - (CHANGES IN STOCKS OF FERTILIZERS)

Production grants are under item (7) in the output accounts, but are here matched up with the appropriate variable. In the TFP calculations, these grants will affect only the share weights, but in a production data set, factor prices should be adjusted to include payments of this kind, so that they represent the opportunity cost to farmers. Finally, for recent years pesticide is listed as a separate variable, and could possibly be best aggregated with fertilizers, to give an agricultural chemicals category. For the TFP index this does not matter, and pesticide is included in the mess of items under Miscellaneous Expenditure.

(MACHINERY SERVICES) = (TOTAL MACHINERY (REPAIRS, FUEL AND OIL,
OTHER EXPENSES)) + (DEPRECIATION ON PLANT, MACHINERY AND
VEHICLES) + (INTEREST)

This attempts to measure user cost by summing running costs, depreciation and interest. Depreciation is under item (18) and Interest under item (20). Interest is the least satisfactory. It is described as interest on commercial debt for current farming purposes; i.e. excluding interest on land purchase (DNIC, Table I). MAFF (1984) says that the largest component is interest on bank borrowing.

How much of this could actually be allocated to machinery, as opposed to building and works, is not clear. Since the allocation is not crucial to the TFP calculations, this approach will do for now. For production data, the interet charges imputed to the value of machinery capital stock could be calculated but this is itself a less than satisfactory approach.

(BUILDINGS AND LAND IMPROVEMENTS) =
(TOTAL FARM MAINTENANCE) + (DEPRECIATION ON BUILDINGS
AND WORKS)

Like machinery, the aim here is to treat buildings and land improvements as a capital stock, and to then calculate user cost as a flow variable. The items included can be viewed as running costs and depreciation.

Farm maintenance may include elements of interest charges but probably some of the Interest (item 20) allocated to machinery should be attributed to this variable. Again, it matters little for the TFP calculation.

(MISCELLANEOUS EXPENDITURE)

Electricity, veterinary expenses, pesticides, rates and other miscellaneous costs (MAFF, 1984).

(LABOUR) = (HIRED LABOUR) + (FAMILY LABOUR)

Hired and family labour is reported after item (20). In fact, information from the HMSO Annual Review of Agriculture was used to improve this input. Basically, the wage bill, divided by the wage rate, multiplied by average hours worked gives a sensible series. This is further explained in section six, below. The farmer himself is not included and nor is his wife. They could be allocated say 60 hours a week farm input series and imputed a wage in the weight calculation.

(LAND) = (NET RENT)

This calculation is complicated by the fact that the treatment of rent changed in 1980, as explained in paragraph (6) above. Basically the pre-1980 net rent concept, which imputes rent to owner occupiers, was used to calculate the weights, while the land input series itself was taken from Agricultural Statistics for the UK (various issues).

SUMMARY

Several difficulties are apparent on the input side, although many variables do make some economic sense. Comment on the treatment of the livestock sector on both the input and output sides of the account, would be particularly appreciated.

The series for labour, interest and net rent require information from other sources, not because we are deviating from the accounting framework, but because the DNIC Appendix Table B stops at Net Product. That is, the constant price series needed to construct these variables are not available. Hence the different treatment of labour, and land input series. Interest too is a problem since it must be converted to a constant price basis. This is referred to again in section six.

One item on the DNIC accounts has been deliberately omitted. The final line of the table, entitled Farm Income has been interpreted as being the returns to the labour of the farmer and his wife (included, by other means, under LABOUR) and the return to the farmer's managerial ability and/or on-farm technical change. In agricultural production, the same inputs can be combined more or less well and the timing and manner of farm operations can crucially affect the level of output per unit of inputs. These elements of productivity change may be called returns to managerial ability, or to on-farm or informal R & D[7], or disembodied technical change. Whatever the terminology, they should form a part of the residual, or the change in the productivity index.

Informal R & D raises a problem, in that it does contribute to productivity growth, but there is no obvious explanatory variable. Changes in productivity are generally explained by R & D expenditures, extension expenditures, farmer education and the weather. Farmer education could possibly fulfill this role, but possibly, Farm Income, net of the returns to labour element, may be a better alternative.

5) THE DIVISIA INDEX AND TORNQVIST-THEIL APPROXIMATION

Given the production function of equation (1), the aggregation problem is to find a procedure for

[7]. The farmer's role in technological change may involve considerable real resources. Evenson (1982) suggests that U.S. farmers spend as much as 25% of their time screening new technologies.

computing total output, Y, and its price, P, such that

$$PY = \sum_{i=1}^{m} p_i y_i \qquad (2)$$

where p_i, $i = 1, \dots m$, are the prices of the set of m outputs.

Similarly, for the input set the problem is to find the aggregate, X, of the p conventional inputs and its price, R, such that

$$RX = \sum_{j=1}^{p} r_j x_j \qquad (3)$$

where r_j, $j = 1, \dots p$, are the conventional input prices. Since the aggregation problem is essentially the same for inputs as for outputs, for brevity it will be dealt with here in terms of outputs only.

Both relationships (2) and (3) must hold not just at a particular point in time, but through changes in time also. Therefore, differentiate equation (2) totally with respect to time, t:

$$P \frac{dY}{dt} + Y \frac{dP}{dt} = \Sigma\, p_i \frac{dy_i}{dt} + \Sigma\, y_i \frac{dp_i}{dt}$$

Dividing both sides by PY, and multiplying each term in the first summation on the right hand side by y_i/y_i and each term in the second summation by p_i/p_i then gives:

$$\frac{1}{Y} \frac{dY}{dt} + \frac{1}{P} \frac{dP}{dt} = \Sigma \frac{p_i y_i}{PY} \frac{1}{y_i} \frac{dy_i}{dt} + \Sigma \frac{p_i y_i}{PY} \frac{1}{p_i} \frac{dp_i}{dt}$$

Now let $\frac{1}{Y}\frac{dY}{dt} = \dot{Y}$, the growth rate of aggregate output; similarly $\frac{1}{P}\frac{dP}{dt} = \dot{P}$, $\frac{1}{y_i}\frac{dy_i}{dt} = \dot{y}_i$ and $\frac{1}{p_i}\frac{dp_i}{dt} = \dot{p}_i$; and let $\frac{p_i y_i}{PY} = s_i$ the share of output y_i in total revenue:

$$\dot{Y} + \dot{P} = \Sigma\, s_i \dot{y}_i + \Sigma\, s_i \dot{p}_i$$

Now assume that

$$\dot{Y} = \Sigma\, s_i \dot{y}_i \qquad (4)$$

and $$\dot{P} = \Sigma\, s_i \dot{p}_i \qquad (5)$$

Thus, the growth rate of aggregate output (and its price) must equal the weighted sum of the growth rates of the individual output (price) growth rates, the weights being the revenue shares of each output.

Integrating equation (4) between time (t-1) and time t gives us

$$\frac{Y(t)}{Y(t-1)} = \exp\{ \int_{t-1}^{t} \Sigma\, s_i \dot{y}_i \, dt\} \qquad (6)$$

Equation (6) defines the Divisia index for aggregate output. This index, however, is in terms of continuous time. Since available data is discrete, it is not possible to use the Divisia index in this form empirically and necessary to compute a discrete approximation. The shorter the time periods used for measurement, the closer these discrete approximations will be to the true Divisia index.

In order to evaluate the integral in equation (6), it is necessary to have some information about the revenue shares, i.e. about the functional relationships $s_i = s_i(t)$; this will depend on the production technology.

For example, if production is such that it can be described by a Cobb-Douglas production function which is separable in outputs and inputs, the first order conditions for profit maximization require that all the revenue shares, s_i, are constant. In this case, equation (6) becomes:

$$\frac{Y(t)}{Y(t-1)} = \prod_{i=1}^{m} \left[\frac{y_i(t)}{y_i(t-1)}\right]^{s_i} \qquad (7)$$

Thus, when production is Cobb-Douglas a geometric index provides a natural discrete approximation to the Divisia index. When an index number corresponds in this way to a particular production function, it is said to be "exact" for that production function. It is a simple matter to show that the Laspeyre's and Paasche indices, which are the index numbers predominantly used in Britain, are themselves exact for the linear production function.

This raises an important issue, for both Cobb-Douglas and linear production functions impose restrictions on production which may not be valid. Using a geometric index assumes Cobb-Douglas production with constant revenue shares for outputs and constant factor shares for inputs; if these shares are observed to stay constant over time, a geometric index is appropriate; if not, another aggregation procedure should be used.

Similarly, using arithmetic indices like the Laspeyre's and Paasche, which are exact for linear production functions, implies that all outputs (or inputs) are perfect substitutes. For an aggregate output index, this means that a decrease in the relative price of any one output would cause its production to be discontinued altogether and another output produced instead. Such drastic changes in production are rarely observed and few economists would argue that linear production functions are good approximations to the real world, yet this is what the wide use of Laspeyre's indices implies.

There are two ways of improving the accuracy of any discrete approximation to the Divisia index: (i) use shorter time periods in data collection, but this may not be possible, (ii) use an approximation which does not impose restrictions on production.

The Tornqvist-Theil Index

The Tornqvist-Theil approximation to the Divisia index falls into category (ii) and is therefore superior to other index numbers for measuring TFP. Using the same notation as above, the Tornqvist-Theil indices for aggregate output and aggregate input are given by

$$\ln\left(\frac{Y(t)}{YTt-1)}\right) = \sum_{i=1}^{m} \frac{1}{2}(S_i(t)+S_i(t-1))\ln\left[\frac{y_i(t)}{y_i(t-1)}\right] \quad (8)$$

$$\ln\left(\frac{X(t)}{X)t-1)}\right) = \sum_{j=1}^{p} \frac{1}{2}(C_i(t)+C_j(t-1)\ \ln\left[\frac{x_j(t)}{x_j(t-1)}\right] \quad (9)$$

where $C_j = \frac{r_j x_j}{RX}$ is the share of input x_j in total cost.

The TFP index is then:

$$\frac{TFP(t)}{TFP(t-1)} = \frac{Y(t)/Y(t-1)}{X(t)/X(t-1)}$$

Diewert (1976) has shown that the Tornqvist-Theil index is exact for the homogeneous translog production function proposed by Christensen, Jorgenson and Lau (1971, 1973), which is a "flexible" function form in the sense that it provides a second order approximation to any arbitrary production function. As a consequence it has the important advantage that it does not require inputs and outputs to be perfect substitutes, as the Laspeyre's index does; if the relative price of an output decreases, the producer decreases its production, producing more of other outputs instead, until all the marginal productivities are proportional to the new prices.

Chained Index Numbers

The discrete approximations to the Divisia index given in equations (6), (7) and (8) have all compared one time period with another. However, when constructing a TFP index, we are interested in a multi-period time series. As well as deciding on an appropriate discrete approximation, it is necessary to choose between two possible procedures for obtaining such a multi-period series. A particular time period may be chosen as a fixed base and an index number computed for all the other periods compared with this base using the chosen index number formula. Alternatively, a chained index may be found by calculating the index number for each period compared with the previous period, and multiplying these indices cumulatively to obtain a time-series based on one particular period.

For example, if we have data on output in years t=0, 1, 2 and 3, we may compute either a fixed base time series for aggregate output:

$$\frac{Y(1)}{Y(0)}, \frac{Y(2)}{Y(0)}, \frac{Y(3)}{Y(0)},$$

or we may obtain a chained index:

$$\frac{Y(1)}{Y(0)}, \frac{Y(2)}{Y(0)} = \frac{Y(1)}{Y(0)} \cdot \frac{Y(2)}{Y(1)}, \frac{Y(3)}{Y(0)} = \frac{Y(1)}{Y(0)} \cdot \frac{Y(2)}{Y(1)} \cdot \frac{Y(3)}{Y(2)}$$

The computational difference between a Laspeyre's index and a Tornqvist-Theil index is that the former holds all the weights fixed at their base period levels, while the latter uses weights from both the base and comparison periods. The chaining procedure is preferable to the fixed base procedure,[8] because weights from every year are made use of in constructing the time series, whichever approximation is adopted.

<u>ATFP index for UK agriculture</u>

Whittaker has suggested a method for computing a TFP index for UK agriculture, using mainly DNIC data, which is part Laspeyre's and part Tornqvist-Theil indices. The same method is used in this paper. Essentially, the DNIC output and input values at constant prices series are used to obtain indices for the five outputs and nine inputs described in section four; these are all, therefore, Laspeyre's indices. The five outputs are then aggregated according to equation (8) and the nine inputs according to equation (9). The revenue shares in equation (8) and cost shares in equation (9) are obtained from the DNIC output and input values at current prices series.

The aggregate output and input indices obtained in this way are therefore a hybrid: Laspeyre's at the initial level of disaggregation, but Tornqvist-Theil at the final level of aggregation.

6) <u>APPLICATION TO UK DATA</u>

As already stated, data was mainly drawn from two sources (1 and 2) and supplemented by two others (3 and 4), namely:

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[8]. See, for instance Diewert (1978) on this issue. A major cause of discrepancies that has not been tackled in the paper is quality adjustment. This was discussed in Thirtle (1986), which also showed the differences between the U.K. productivity indices. Godden (1985) does attempt quality adjustment in his work.

1) The MAFF Departmental Net Income Calculation, Annual Review (DNIC), various issues.

2) The CSO Annual Abstract of Statistics (AAS), section 9, various issues.

3) The HMSO Annual Review of Agriculture (ARA), various issues and,

4) MAFF Wages and Employment in Agriculture: England and Wales, 1960-80, Government Economic Series Working Paper Number 52.

Three areas of potential difficulty were identified: firstly, the DNIC statistics were only compiled on a calendar year basis since 1971. Consequently it was necessary to supplement these series for the years 1967-70 from the AAS. Secondly, in order to calculate the constant price series for both inputs and outputs, it was necessary to splice together series which were initially reported using 1975 prices and more recently 1980 prices. This aim was achieved by using comparable values for 1974-76. Thirdly, statistics published in both the AAS and the ARA, have only been published up to and including 1986. Therefore, when required, 1987 values were estimated according to assumptions elaborated below.

The next section will state the problems encountered with the construction of the output series and the following section, will deal with the input equations.

The Output Equations

The only computational difficulties encountered involved the series for Own Account Capital Formation (OACF - item 5). The series had to be disaggregated into breeding livestock, a component of output equation 3 and other assets, equation 5. Although the DNIC figures disaggregated OACF the necessary constituent parts, the AAS (used for the 1967-70 observations) did not. Consequently, the AAS aggregate OACF series was 'split out' based on the DNIC weights for the respective component series averaged over 1970-87.

A second problem arose in the construction of the constant price series for breeding livestock and other assets. The solution adopted was, to 'impute their values' from their respective current priced equivalents, multiplied by the ratio of OACF (constant prices)/OACF (current prices). Equation 10 below describes the procedure used to compute OACF: Other Assets:

$$\text{OACF: Other Assets(KP)} = \frac{\text{Total OACF(KP)} * \text{Other Assets(CP)}}{\text{Total OACF(CP)}} \qquad (10)$$

where CP equals current price and KP constant price.

The Input Equations

The computation of the input equations was more problematic, beginning with equation 1, Feed.

The DNIC intermediate output series, needed to be disaggregated into intermediate feed, a component of equation 1 and intermediate seed, a component of equation 2. Although the DNIC published current priced series, the constant prices are only reported at an aggregate level. The AAS does publish disaggregated series, however discrepancies between the two total immediate output series suggest different computational procedures had been employed, thus requiring its omission. Consequently, the constant price series were calculated using their respective current priced equivalents as weights, as in equation 10 above.

Further problems were encountered with the change in stocks data which is composed of purchased feed, a component of input equation 1 and fertiliser, a component of input equation3. Although the DNIC report separate figures for both categories, the AAS simply reports a comparable aggregate series, entitled Value of Physical Usage of Stock, item 15. Problems are further complicated because unlike the series for OACF and Intermediate Output, these series can take on either positive or negative values therefore making decomposition difficult. In the absence of this information it is assumed that both series of stocks take on positive values. The aggregate series was split using average weights for the current priced series between 1971-87; 0.5185 and 0.4815 respectively, for feed and fertilizer. However, the DNIC data tends to exhibit a cyclical pattern. Fortunately, possible errors will be insignificant owing to the relatively small magnitudes involved.

The constant priced series were similarly derived by weighting the constant priced aggregate by the respective current priced series weights.

Examining equation 4, as the DNIC figures only provided a constant priced aggregate for Production Grants, the AAS was used as a source for the series entitled Production Grants: fertiliser and lime. The 1987 observation was assumed to be zero; no grants having been given for the past decade.

Next, consider equation 5, the Machinery series, in particular its depreciation and interest components. Interest is defined as that accruing to commercial debt incurred for current farming purposes, thereby excluding payments made for land purchases. However, interest payments on buildings and works, in theory a component of equation 6, still remain, thus overstating the true size of this particular input cost share equation.

The constant priced interest series was derived by multiplying the current price interest series by the Internal Index of Purchasing Powe (I.I.P.P.) as published in the AAS. The IIPP is basically the reciprocal of the Retail Price Index, showing the purchasing power of 1 at different points in time. Due to the present unavailability of the 1987 observation, inflation was assumed to be 4%, and the IIPP calculated accordingly.

Looking at equation 6, improvements to buildings and land, problems arose due to changes in the accounting conventions pre and post 1969. Post 1969, depreciation (item 9 AAS), was decomposed into two components: plant, machinery and vehicles and buildings and works. Pre 1969 depreciation was charged firstly to tenants, sub-divided into machinery and other, and secondly, landlords. In order to cope with this discrepancy between the two periods, it is assumed that depreciation on plant and machinery in 1968 and 1969 equals 90% of the total figure, given the tenants depreciation ratio between plant and buildings was found to be constant at ratio of 90:10 between 1967-74. A similar assumption is made in order to estimate the total of both tenants and landlords depreciation charged to machinery (equation 5) for the years 1968 and 1969.

The miscellaneous expenditures series, input equation 7 is inflated due to the inclusion of pesticides. Ideally, the latter would have been included as a separate input, had figures been available pre 1976.

With reference to equation 8, the series for labour was composed of both hired labour and family labour. The latter included managers and partners, but omitted both farmers, and the spouses of farmers, directors and managers engaged in farmwork. To correct for this deficiency, the series was first supplemented with data on the man equivalents of spouses of farmers, directors and partners engaged in farmwork, 1960-80 as reported in Lund et al. (1982), Appendix 3. Although only published for England and Wales, such series were inflated by weight of 1.207, the average of the ratio of spouses England and Wales to spouses UK for the years 1977-80 when the Lund et al. and ARA series overlap. The ARA UK series 1980-87 for spouses was weighted by 0.35 to convert it into man equivalents and a value imputed based upon the earnings of hired labour as reported in the ARA. Unlike the DNIC statistics, the series for spouses fails to include the employers national insurance contributions in respect of that element of the workforce.

The labour series was secondly supplemented by a series for the value of farmers labour, based on man equivalents, again published by Lund et al. (1982), Appendix 3. To be consistent with the 1960-80 observations, the later figures for total number of farmers was divided into full and part-time, using weights taken from Lund et al., averaged between 1960 and 1980, giving a figure of 0.7618.

Unlike earlier equations, a quantity based series for labour, measured in millions of hours worked, was employed, rather than a constant priced series for labour. In theory, due to the construction of the index, the constant prices should simply cancel out when used to construct an index, thus leaving simply a quantity index.

Equation 9, the Net Rent equation, was compiled to impute a value for all agricultural land, not just that element currently rented, as the DNIC and AAS figures reflect. The series was compiled from various tables within the ARA as follows: Firstly, the index of gross rent for GB (England, Scotland and Wales) was computed by splicing the 1975 and 1980 base year series together using weights averaged over the period 1979-81. Secondly, to avoid double counting, the gross rent index had to be deflated to one index of net rent i.e. less expenses incurred in maintenance plus the benefit value of property if used for dwelling purposes. The DNIC Sources and Methods publication, under the heading of Farm Maintenance, currently estimated repairs and maintenance to be 17% of rents for England and Wales and 18% for Scotland. Consequently, the gross index was deflated by 17%. Thirdly, to convert the index to a series of current prices, the 1975 values of net rent, England, Scotland and Wales, are weighted by the respective countries hectares and the index suitably converted.

The constant priced net rent series used was in fact a quantity index based on the number of hectares of agricultural land (millions). Whittaker (1983), assumed that the amount of land taken out of agricultural production was negligible. This might have been the case between 1967 and 1980, the time period of her comparison, but between 1967-87, hectarage actually declined by nearly 5%.

Finally, this leads us to the bottom line, namely the Divisia TFP indices actually constructed. Table 1 below reports two of them: firstly a Divisia index calculated using 1967 as the base year and secondly a conventional chained Divisia index.

Table II also shows a Divisia index calculated using 1967 as the base year, and secondly a chained Divisia index. These were calculated using the DNIC data with as little rearrangement as possible, in order to investigate Evenson's (1987) proposition that the accounting framework and the production function approach give the same results.

Figure I compares all four indices, and shows that although the two Evenson indices are very close to each other and so are the two we have rearranged, the Evenson versions rise less quickly. However, Figure Ii shows the first differences of our chained Divisia index and Evenson's chained index. Clearly the two are very close, as is confirmed by the correlation coefficients reported in Table III.

Table 1 : Divisia Indices

Time	Base 1967 TFP	Chained TFP
1967	1.0000	1.0000
1968	1.0190	1.0178
1969	0.9992	0.9973
1970	1.0822	1.0789
1971	1.0470	1.0461
1972	1.0690	1.0692
1973	1.0591	1.0617
1974	1.0239	1.0302
1975	1.0056	1.0234
1976	1.0653	1.0814
1977	1.0798	1.0932
1978	1.0718	1.0870
1979	1.1468	1.1630
1980	1.1489	1.1651
1981	1.2185	1.2348
1982	1.1868	1.2014
1983	1.2840	1.3036
1984	1.2166	1.2393
1985	1.2750	1.2981
1986	1.2695	1.2933

Table 2 : 'Evenson's' Divisia Indices

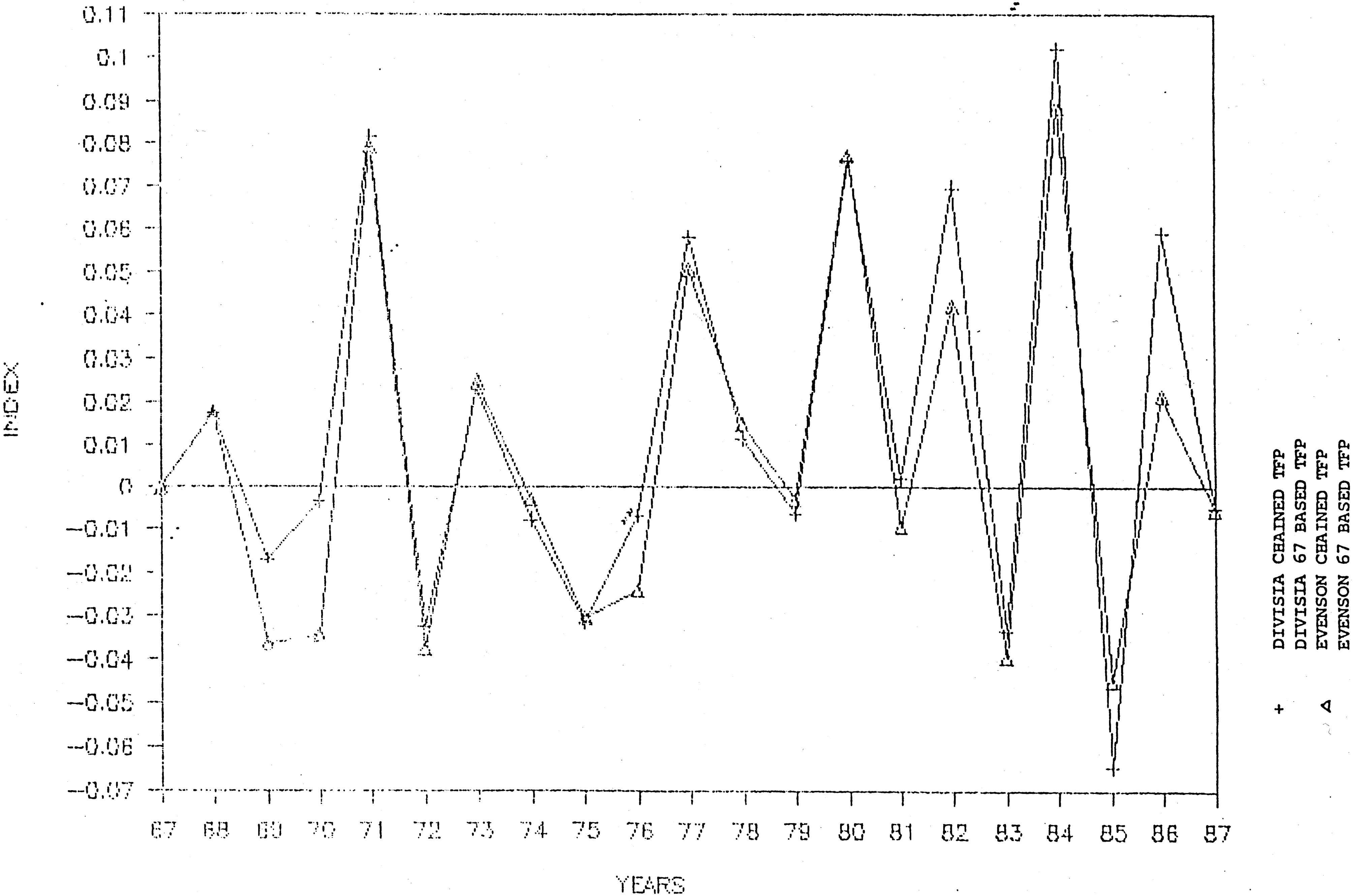
Time	Base 1967 TFP	ChainedTFP
1967	1.0167	1.0178
1964	0.9754	0.9814
1969	0.9443	0.9468
1970	1.0225	1.0256
1971	0.9825	0.9881
1972	1.0031	1.0130
1973	0.9966	1.0100
1974	0.9653	0.9793
1975	0.9344	0.9549
1976	0.9858	1.0052
1977	1.0029	1.0204
1978	0.9982	1.0177
1979	1.0736	1.0946
1980	1.0645	1.0853
1981	1.1063	1.1273
1982	1.0682	1.0875
1983	1.1524	1.1758
1984	1.1056	1.1308
1985	1.1283	1.1524
1986	1.1222	1.1471

Table 3 : Correlation Coefficients Between the TFP Indices, Calculated Using First Differences

	Divisia 67 Based	Divisia Chained	Evenson 67 Based	Evenson Chained
Divisia 67 Based	1	O.995	0.910	0.900
Divisia Chained		1	0.906	0.903
Evenson 67 Based			1	0.996
Evenson Chained				1

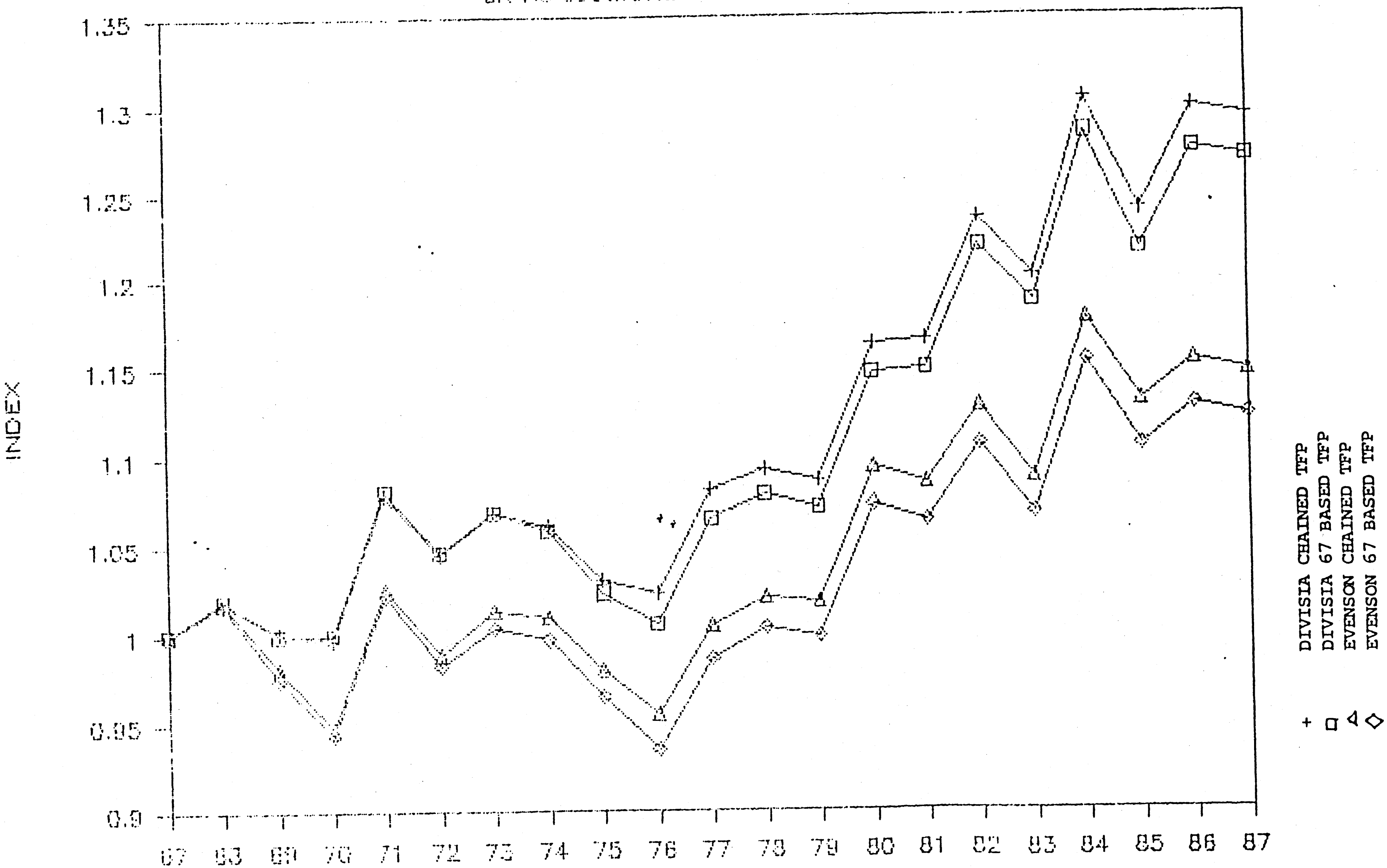
COMPARISON OF THE CHAINED TFP INDICES:

MEASURED IN 1st. DIFFERENCES



TOTAL FACTOR PRODUCTIVITY INDICES:

UK AGRICULTURE. 1967--1987.



7) CONCLUSION

This paper began as a simple attempt to update Whittaker's (1984) TFP index. In the light of recent evidence on the derivation of TFP indices (Evenson, Landau and Ballou, 1987), some aspects of the derivation were explored further than was originally intended. Particularly, Evenson et.al. show that if the index is of the Divisia type, the same result will follow from the accounting derivation as from the production function derivation. This led us to compare an index derived from an unchanged national income accounting framework with an index derived from data that had been modified to better suit the production function approach.

The results differ, but the exact cause cannot be determined. However, one probable reason for deviation is that the level of aggregation is different for the two series.

This problem is quite fundamental, since the aggregation procedure used in the DNIC Blue Books is a base-weighted Laspeyres index, whereas we have used a chained Divisia index. Hence the outcome is still practically pure Laspeyres if only the very top level of aggregation is Divisia. Even if the Divisia procedure were used down to the lowest level of aggregation given int he DNIC Blue Books, the result would still be predominantly a Laspeyres index. To derive a genuine Divisia index comparable to the world of Ball (1985) would require access to the raw data and a considerable input of labour.

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