Productivity and Farm Profit – A Microeconomic Analysis of the Cereal Sector in England and Wales

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Abstract

This paper implements the profit change decomposition methodology developed by Grifell-Tatjé & Lovell (1999). Profit change over time is first decomposed into a price effect and a quantity effect; the quantity effect is then decomposed into a productivity effect and an activity effect; in turn, the productivity effect is subdivided into a technical efficiency effect and a technical change effect, while the activity effect is divided into a scale effect, resource mix effect and product mix effect. The end result is therefore a measure of six distinct components of profit change.

The methodology is used to investigate profit changes for a sample of cereal farms drawn from the Farm Business Survey in England and Wales for the period 1982 to 2000. The results of the analysis show an overall decline in profit levels for the period at the average speed of £4,400 annually, with the major part of this decline attributable to a negative price effect amounting to £7,000 annually on average. However, this was to some degree offset by a positive quantity effect largely driven by the positive contribution of technical change to profit growth, worth £4,000 annually on average. .

I. Introduction

The literature on productivity and efficiency measurement has grown dramatically since the publication of seminal papers by Solow (1956), Charnes, Cooper & Rhodes (1978), Aigner & Chu (1968) and Aigner, Lovell & Schmidt (1977). Increasingly sophisticated methodologies have been developed to tackle noisy data; reduce the restrictions imposed by functional forms and behavioural assumptions; identify the components and determinants of productivity growth; and address many other theoretical and econometric issues. The techniques have been applied to a large variety of contexts and sectors, in particular agriculture, where hundreds of published papers on productivity and efficiency analysis exist. In the UK, productivity growth in agriculture has been the focus of a recently completed DEFRA project (Department for Environment, Food and Rural Affairs, 2003), the results of which are summarised in a special issue of the Journal of Agricultural Economics (July, 2004).

Yet, as noted recently by Lovell (2001), while economists are interested in the efficiency and productivity with which businesses operate, business people are concerned with their profitability. It is clear that these concepts all relate to each other: all things being equal, a more productive business is also more profitable, and, in a temporal framework, fast productivity growth translates into fast profit growth. However, in the real world, ‘other things’ are not equal, which makes it difficult to decompose profit variation into variation in efficiency and productivity, and variation in other sources. The same set of arguments applies to agriculture, where farmers and policy makers are primarily interested in farm profit and the returns to the farm's fixed assets, and not efficiency and productivity *per se*. We therefore propose to investigate the relationship between profit change and productivity growth in the UK cereal sector, and to show how this decomposition brings useful insights into the current debate on agricultural policies.

The linkage between productivity change and profit has been previously analysed by the management accounting literature (see Miller, 1984), but this literature lacks a sound underlying theoretical framework and overall consistency. However, more recently, production economics has been used on a few occasions to guide this inquiry (Grifell-Tatjé & Lovell, 1999; Han and Hughes, 1999) and, in this paper, we propose to implement the methodology developed by Grifell-Tatjé & Lovell (1999). The end result is a measure of six distinct components of profit change, which can help us answer important questions for the cereal sector in England and Wales. For instance, how significant has been the adoption of new technologies, which drives technological change, for the growth of farm profit? What has been the impact of the recent decline in cereal prices on farm profits? Does output diversification represent an effective way of limiting the recently observed decrease in farm income? Do intensification and/or growth in farm size represent realistic options for farmers to maintain their income levels? Answers to these questions have obvious implications for, among others, R&D, structural and price policies.

To the best of our knowledge, ours is the first attempt to decompose farm income growth into variations in productivity and variation in other sources. It is worth emphasizing that the approach differs from the more standard investigation of profit/cost efficiency[i] in the sense that it does not rely on the assumption of cost minimisation or profit maximisation. What we describe is akin to an accounting relationship between profit change and productivity change, which is valid for any criterion of economic optimality. This is an attractive feature of the approach for the analysis of farm profit because farmers tend to maximise multiple criteria.

The paper is structured in the following way. The methodology is reviewed in section II, followed by a brief exposition of the way it is implemented. The data set and variable construction are described in section IV and section V presents the results of the analysis. Finally, results are discussed and conclusions made in section VI.

II. Methodology

Following Grifell-Tatjé & Lovell (1999), we consider a farm using an input vector x of dimension K to produce an output vector y of dimension M. The corresponding price vectors are denoted by w and p respectively. Note that vector w includes both market prices for those inputs that are purchased outside of the farm, and shadow prices for the fixed factors of production. In each period t, total economic profit generated on the farm is simply:

$$\pi^t = p^t y^t - w^t x^t \qquad (1)$$

We now develop a decomposition procedure of farm profit growth (π^{t+1}- π^{t+1}) between periods t and $t+1$, which is easily derived from commonly available farm-level data and relies on the microeconomic theory of the firm. The first stage is straightforward and has long been acknowledged in the financial literature (e.g., Kurosawa, 1975).

Stage 1: The profit change between periods *t* and *t+1* decomposes as:

$$\pi^{t+1} - \pi^{t} = \underbrace{(y^{t+1} - y^{t})p^{t} - (x^{t+1} - x^{t})w^{t}}_{\text{Quantity Effect}} + \underbrace{(p^{t+1} - p^{t})y^{t+1} - (w^{t+1} - w^{t})x^{t+1}}_{\text{Price Effect}} \qquad (2)$$

The price effect captures the impact of price changes on profit, for a given production plan of the farm. The quantity effect measures the change in profit attributable solely to variations in the farm's production plan, because prices are held constant. Note that the quantity effect is calculated by using base-period prices and is therefore interpretable as the difference between two Laspeyres-type quantity indices; the price effect is calculated from current-period quantities, and is therefore interpretable as the difference between two Paasche-type price indices. A similar decomposition would follow from choosing base-year quantities and current-year prices instead. The quantity effect can then be decomposed into five additional effects, through two additional stages, which are based on distance functions that we now need to define. The within-period output distance function is defined as (Coelli *et al.,* 1998):

$$D_o^t(x^t, y^t) = \min\left\{\delta : y^t / \delta \in P^t(x^t)\right\} \qquad (3)$$

where $P^t(.)$ denotes the output set derived from the period-*t* technology. Because the input-output combination (x^t, y^t) is observed in year *t*, $\delta=1$ is always technologically feasible and it follows that the within-period output distance function is necessarily smaller than or equal to unity. Its value represents the percentage of maximum achievable output that the firm produces, given its input vector and the year-*t* technology. It also corresponds to the Farrell-type output orientated measure of technical efficiency. The concept is easily extended to measure the distance of any input-output combination *(x, y)* with respect to any particular technology *f*:

$$D_o^f(x, y) = \min\{\delta : y/\delta \in P^f(x)\} \qquad (4)$$

where the only new notation, $P^f(x)$, represents the output set associated with technology *f*. Because the production plan *(x,y)* is not necessarily observed when technology *f* is available, however, we cannot conclude *a priori* how the value of D^f_o compares to unity. In the remainder of the paper, we use the adjacent-periods output distance functions $D^{t+1}{}_o(x^t, y^t)$ and $D^t{}_o(x^{t+1}, y^{t+1})$, as well as the mixed-periods distance function $D^{t+1}{}_o(x^{t+1}, y^t)$, which can all be greater or smaller than unity.

Our decomposition also involves the input distance function, which was first introduced by Shepard (1970). With respect to the within-period technology, it is defined as:

$$D_i^t(x^t, y^t) = Max\{\rho : x^t/\rho \in L^t(y^t)\} \qquad (5)$$

where $L^t(y^t)$ denotes the input requirement set, given the technology in period *t* and the output vector y^t. It measures the largest factor of proportionality ρ by which the input vector x^t can be scaled down in order to produce a given output vector y^t with the period-*t* technology. The within-period input distance function takes a value no smaller than unity and its reciprocal is the well-known Farrell (1957) input-based index of technical efficiency. As discussed previously for the output distance function, it is easily extended to accommodate any input-output combination *(x, y)* and any technology *f*. We now proceed to present the second stage of our decomposition.

Stage 2: The quantity effect between period *t* and period *t+1* decomposes as

$$\underbrace{(y^{t+1}-y^{t})p^{t}-(x^{t+1}-x^{t})w^{t}}_{\text{Quantity Effect}}=\underbrace{p^{t}[(y^{b}-y^{t})-(y^{c}-y^{t+1})]}_{\text{Productivity Effect}}+\underbrace{[p^{t}(y^{c}-y^{b})-w^{t}(x^{t+1}-x^{t})]}_{\text{Activity Effect}} \quad (6)$$

where $y^{b}=y^{t}/D_{o}^{t+1}(x^{t},y^{t})$ is interpreted as the maximum output achievable with input vector x_t and year-$(t+1)$ technology; while $y^{c}=y^{t+1}/D_{o}^{t+1}(x^{t+1},y^{t+1})$ is interpreted as the maximum output achievable with input vector x_{t+1} and year-$(t+1)$ technology. Hence, the difference $(y^b$-$y^t)$ represents the distance of the observed input-output combination $(x^t,\ y^t)$ from the year $(t+1)$ technological frontier; while $(y^c$-$y^{t+1})$ represents the distance of the observed input-output combination $(x^{t+1},\ y^{t+1})$ from the same frontier. It follows that the inside of the square bracket of the productivity effect measures the extent to which the firm got closer to a given technological frontier between periods *t* and *t+1*, which is a way of assessing its productivity growth[ii]. As should be expected, a firm getting nearer the technological frontier generates a productivity effect that contributes positively to profit growth.

The activity effect is not calculated from observed output vectors but from the technically efficient output vectors y^b and y^c given a single (period-*(t+1)*) technology and the two input vectors x^t and x^{t+1}. It therefore nets out any possible change in efficiency and technology between the two periods. What is left is the change in profit resulting from changes in the scale of operation, the choice of input mix and the choice of output mix (scope), as is made clear in stage 3.2 of the decomposition below. In the one-input, one-output case, the activity effect would simply correspond to the move along the year-*(t+1)* production function between the technically-efficient projections of production plans (x^{t+1}, y^{t+1}) and (x^t, y^t). The next stage of the decomposition involves further disaggregation of the productivity and activity effects.

Stage 3.1: The productivity effect between periods t and $t+1$ decomposes as:

$$\underbrace{p^t[(y^b - y^t) - (y^c - y^{t+1})]}_{\text{Productivity Effect}} = \underbrace{p^t(y^b - y^a)}_{\text{Technical Change Effect}} \underbrace{- p^t[(y^c - y^{t+1}) - (y^a - y^t)]}_{\text{Technical Efficiency Effect}} \quad (7)$$

where: $y^a = y^t / D_o^t(x^t, y^t)$ represents the maximum output vector achievable from input vector x_t and year-t technology. The difference $(y^b - y^a)$ captures by how much that maximum changes between two adjacent periods. Given that the input vector x_t and the output mix (defined by y_t) are held constant, this change is solely attributable to the evolution of the technology between the two periods. If there is technological progress (regression), $(y^b - y^a)>0$ (<0), and the technical change effect is clearly positive (negative). Vector y^c corresponds to the proportional expansion of vector y^{t+1} which reaches the period $t+1$ technological frontier (i.e., it is the technologically efficient output vector associated with (x^{t+1}, y^{t+1}) and the period-$(t+1)$ technology). It follows that the difference $(y^c\text{-}y^{t+1})$ captures the degree of technical inefficiency of the farm in year $t+1$, while $(y^b\text{-}y^t)$ captures the degree of technical inefficiency of the farm in year t. The term in square brackets of the technical efficiency effect therefore measures the change in technical inefficiency between two adjacent periods, aggregated across outputs using base-year prices. Clearly, an improvement in technical efficiency makes a positive contribution to profit growth.

The third stage of the profit decomposition concludes with the disaggregation of the activity effect.

Stage 3.2: The activity effect from period *t* to period *t+1* decomposes as:

$$\underbrace{p^t(y^c - y^b) - w^t(x^{t+1} - x^t)}_{\text{Activity Effect}} = \underbrace{p^t(y^c - y^d)}_{\text{Product Mix Effect}} \underbrace{- w^t(x^{t+1} - x^e)}_{\text{Resource Mix Effect}} + \underbrace{p^t(y^d - y^b) - w^t(x^e - x^t)}_{\text{Scale Effect}} \quad (8)$$

where $y^d = y^t / D_o^{t+1}(x^{t+1}, y^t)$. Note that y^c and y^d are both technically efficient vectors given the input vector x^{t+1} and the period-*(t+1)* technology. However, y^c is defined with the same output mix as y^{t+1}, while y^d is defined with the same output mix as y^t. The difference $(y^c\text{-}y^d)$ therefore captures a change in output vector solely attributable to a change in output mix, which is aggregated across products using base-period prices to give the product mix effect. Hence, a positive product mix effect indicates that an improvement in the output-orientated allocative efficiency of the firm makes a positive contribution to profit growth.

The resource mix effect is the mirror image of the product mix effect in input space. It is based on the input vector $x^e = x^t / D_i^{t+1}(x^t, y^d)$. Note that from the definition of y^d, input vector x^{t+1} belongs to the y^d-isoquant defined with respect to the year-*(t+1)* technology. It is also evident that x^e belongs to that same isoquant. The difference between the two input vectors x^{t+1} and x^e therefore lies solely in the input mix, which is the same as that of x^t in the case of x^e. Hence, the resource mix effect measures the potential decrease in cost resulting from the change in the input mix between two adjacent periods. In other words, the resource mix effect reflects changes in the input-orientated allocative efficiency of the firm, with improved efficiency contributing positively to profit growth.

Finally, note that vectors y^d and y^b are two technically efficient output vectors computed with respect to the same year-$t+1$ technology and the same output mix (defined by y^t). The only difference lies in the reference input vector, which is x^t for y^b and x^{t+1} for y^d. Hence, quantity $(y^d\text{-}y^b)$ accounts for the growth in production that is solely attributable to the change in input vectors between two adjacent periods. Using base-year prices to transform these quantity changes into values, we obtain a pure scale effect, or, in other words, the change in profit solely attributable to a change in the level of input use.

This concludes our presentation of the profit decomposition into two effects in the first stage, two effects in the second stage, and five effects in the third stage. It is important to note that the method did not impose any behavioural assumption. This is so because our purpose is not to evaluate the performance of a given farm with respect to an arbitrarily chosen concept of optimality, such as profit maximisation or cost minimisation, but to explain observed inter-annual changes in profit. Hence, in that respect, this study departs fundamentally from the more traditional analysis of farm allocative and economic efficiency, although it also shares a great deal with that type of empirical inquiry.

III. Implementation

While the previous decomposition is conceptually simple, it involves several quantities $(y^a, y^b, y^c, y^d$ and $x^e)$ which are not directly observable. Note, however, that all those quantities are derived from observed output and input vectors as well as the unobserved values of several distance functions. The purpose of this section is to explain how the values of those distance functions can easily be retrieved by DEA-type linear programming problems.

DEA models build a technological frontier by piece-wise linear envelopment of the observed input and/or output vectors (Coelli *et al.*, 1998). Following Grifell-Tatjé and Lovell (1999), we make the assumption that the technology cannot be forgotten, and therefore rule out the possibility of technological regression. This implies that the year-*t* technological frontier is constructed by considering all observations prior to, and including, year *t*. Hence, all the DEA-type problems presented below are sequential rather than contemporary (see Suhariyanto and Thirtle, 2001, for a discussion of the relative merits of the two approaches).

Suppose that we observe the input and output vectors $(x_f^t, y_f^t))$ of a particular farm *f* in any year *t*. We denote by I_s the number of observations on producers that we use to build the technological frontier in each year *s=1, 2, …, t*. The $M \times \sum_{s=1}^{t} I_s$ sequential output matrix Y_s^t in year *t* is defined simply as $\left[y_1^1, y_2^1, \ldots\ldots y_{I_1}^1, y_1^2, \ldots\ldots y_{I_2}^2, \ldots\ldots, y_1^t \ldots\ldots y_{I_t}^t\right]$; similarly, the $K \times \sum_{s=1}^{t} I_s$ sequential input matrix X_s^t is defined as $\left[x_1^1, x_2^1, \ldots\ldots x_{I_1}^1, x_1^2, \ldots\ldots x_{I_2}^2, \ldots\ldots x_1^t \ldots\ldots x_{I_t}^t\right]$. With the above notations, the value of the output distance function evaluated at input-output combination *(x, y)* with respect to the sequential technological frontier in period *p* is inferred from the solution to the following linear-programming problem:

$$
\begin{aligned}
&\left[D_o^p(x,y)\right]^{-1} = \max\theta \\
&s.t. \\
&\theta y \le Y_s^p \lambda \\
&X_s^p \lambda \le x \\
&1^v.\lambda = 1 \\
&\lambda \ge 0
\end{aligned}
\qquad (9)
$$

where λ is a column vector of dimension $\sum_{s=1}^{p} I_s$, and 1^v is a row vector of ones of the same dimension.[iii] By choosing $(x, y)= (x^t, y^t)$ and $p=t$ in problem (9), we retrieve the value of $D_o^t(x^t, y^t)$, from which vector y^a is easily calculated. Similar reasoning allows for calculation of vectors y^b, y^c and y^d. Finally, the input vector $x^e = x^t / D_i^{t+1}(x^t, y^d)$ is retrieved from the solution to the following linear programming problem:

$$
\begin{aligned}
&\left[D_i^{t+1}(x^{t+1}, y^d)\right]^{-1} = \min\phi \\
&s.t. \\
&y^d \le Y_s^{t+1} \lambda \\
&X_s^{t+1} \lambda \le \phi x^{t+1} \\
&1^v.\lambda = 1 \\
&\lambda \ge 0
\end{aligned}
\qquad (10)
$$

Altogether, the method involves solving five different linear programming problems for every farm and every pair of adjacent periods. Hence it is computer intensive as illustrated by the fact that, given the size of our data set, we had to solve 12,510 such problems.[iv]

IV. Data

The farm-level production data is drawn from the Farm Business Survey (FBS) for England and Wales (Department for Environment, Food and Rural Affairs and National Assembly for Wales, 2003) covering the production years from 1982 to 2000. The FBS is an annual survey of more than 2,800 farms that are selected from a random sample of census data that is stratified according to region, economic size of farm and type of farming. It should be noted that only farm businesses above eight European size units (ESU) are included in the FBS. According to Defra (2002) approximately 18% of all holdings classified as cereal farms in England were below 8 ESU in 2000. Accordingly the sample used here cannot be seen to be truly representative of the population of cereal farm holdings in England and Wales although it can be considered to represent those holdings that produce the greater part of cereal output.

A sub sample of 436 cereal farms (defined here as those farms where 60% or more of total revenue is derived from cereal enterprises) observed for varying numbers of years (the mean duration being 6.74 years with the minimum number of years being 3) are extracted from this dataset to form an unbalanced panel totalling 2938 observations.

The variables used in the analysis are constructed as follows:

- Cereal output ($y1$) is constructed as the sum of production (tonnes) over all cereal enterprises for each farm;
- Cereal price ($p1$) is generated by dividing the sum of all revenue from cereal production by quantity of cereal produced on each farm (note that Arable Area Payments are included in revenue);

- Other crops output (*y2*) is the sum of all quantities of all crops other than cereals grown on each farm, measured in tonnes (note that none of the farms in the sample produce any livestock outputs);
- Other crops price (*p2*) is calculated in a similar way to *p1* (again, note that any Arable Area Payments received are included within the calculation of revenue);
- Hours of family and managerial unpaid manual labour (*x1*);
- Price of family and managerial unpaid manual labour (w*1*), calculated by dividing an imputed valuation of payments to unpaid labour by number of hours worked (this imputed valuation is internal to the FBS);
- Hours of all classes of hired labour (*x2*);
- Price of hired labour (*w2*), calculated by dividing payments to hired labour by number of hours worked;
- Area of land utilised for agricultural production (*x3*), measured in hectares;
- Rental price of land (*w3*) (rent is imputed within the FBS for owner occupied farms);
- Quantity of variable inputs (*x4*) – this is an index constructed by summing annual farm expenditures over four major categories: fertiliser, seeds, crop protection products and other general expenses (fuel, water, etc.) and dividing the result by the price index *w4* described below;
- Price of variable inputs (*w4*) – this is a divisia price index created from national DEFRA price indices for the various categories of inputs that make up this aggregate input (1990 = 1), note that since we do not have

price information for inputs at the farm-level we assume that all farms in the sample face the same set of input prices;

- Quantity of capital services (*x5*), which is constructed in an attempt to represent the flow of services emanating from capital stock items such as machinery, buildings and land improvements and which is measured by summation over these elements of maintenance and running costs, depreciation charges and interest on the capital stock and dividing the result by the capital price index (*w5*) described below;
- Price of capital services (*w5*) – another divisia price index created from national DEFRA price indices for the various categories of capital inputs that make *x5* (again, 1990 = 1 and we make the same assumptions for this as were done for *w4*).

Summary statistics for these variables - and for operating profit (simply defined as the result of the product of output quantities and output prices minus the product of input quantities and input prices) – for the sample over the whole period (1982 to 2000) are presented in Table 1. Note that all prices have been deflated to 1990 levels using the appropriate annual price indices published by Defra.

Figure 1 describes the evolution of annual mean operating profit for this sample between 1982 and 2000. As the figure clearly demonstrates, mean profit (in the simple sense that we employ) has been negative over the majority of the period studied. In fact, profit has only been positive, for this sample, for 7 of the 19 years for which we have data. Annual mean operating profit was positive for the first three years of the period covered here, became negative in 1985 and remained so through the rest of the 1980s. There was some recovery close to break-even levels in the early 1990s and then two years of very positive profits in 1995 and 1996. Since 1996 there has been a dramatic decline in profit levels to a low in 2000.

V. Results

The results of implementing the profit decomposition are summarised in Table 2 and Table 3. Table 2 shows average annual changes in profits over the period covered by the sample whilst Table 3 reports cumulative changes in profits, i.e. changes relative to the start of the sample in 1982, expressed on a per annum basis. Each Table reports the total profit change in the second column and then shows how this is decomposed into price and quantity elements in successive columns. The quantity element is then further decomposed into productivity and activity components (which are in turn composed of further sub-components; technical efficiency and technical change in the case of the productivity component, and scale, resource mix and product mix in the case of the activity component). The various elements of the decomposition are shaded within the tables in an attempt to increase the clarity of presentation.

Considering Table 2, total profit change follows a broadly similar pattern of change to that described in Figure 1 excepting those observations for the final few years of the data[v]. Total profit change is negative in 10 of the 18 observed periods, and on average (see the final row of Table 2) total profit declined annually by more than £4,000 between 1982 and 2000, or £72,000 over the entire period. The analysis therefore confirms the conventional wisdom that returns to the resources used in cereal production declined drastically in the 1980s and 1990s, resulting in significantly lower farm incomes and exit from the sector. This decrease in profitability is explained primarily by the price component of profit change that was chiefly negative (for 13 of 18 periods) and on average amounted to approximately £7,000 annually. However, negative price change effects were to some extent offset by a chiefly positive quantity change effect (for 11 of 18 periods) which averaged almost £3,000 a year over the whole period. This quantity change effect is made up of productivity and activity components that themselves can be further decomposed. The productivity effect contributes most (£2,454) to the average positive value for the quantity effect over the whole period, of this a negative value of £1,660 is attributed to the technical efficiency effect whilst the average technical change effect more than offsets this negative amount with a positive value of £4,114. As expected from the use of sequential (rather than contemporary) frontiers in all DEA problems, all the annual values for the technical change effect are positive, but the quantitative results demonstrate that technical change has made a very important and positive contribution to the profitability of this sample of cereal farms throughout the period studied. The activity component of the total quantity effect is generally smaller than the total productivity effect (both annually and on average) totalling £375 annually over the period. Of this total: scale effects are mostly negative (16 of 18 periods) and are almost £1,000 on average between 1982 and 2000; resource mix effects are mostly positive (11 of 18 periods) and are, on average, £1,192 per year for the whole period; and product mix effects

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are mostly positive (11 of 18 periods), but average less than £100 a year for the period sampled.

From Table 3 and Figures 2 to 5 that report changes in profit with respect to the base year, 1982, expressed on a per annum basis, it is easier to determine some broad longer term patterns of profit change occurring within this sample. Figure 2 presents graphically the first step of the decomposition and confirms the previous observation that overall profit declined over the entire period due to a large and negative price effect that was only partially compensated by a consistently positive quantity effect. Further, the figure allows us to identify three distinct sub-periods: from 1982 to 1987, the profitability of cereal farms worsened; from 1987 to 1995, profitability recovered up to its 1982 level; and finally, from 1995 to 2000, profits decreased again. Figure 2 also makes clear that the key determinant of the evolution of farm profit lies with the price effect rather than the quantity effect. Indeed, excluding the first few years, there is a remarkable correlation between the evolution of total profit change and the price effect, while the quantity effect appears relatively constant.

Figure 3 presents the second step of the decomposition. While the picture remains blurry for most of the 1980s, it then becomes evident that it is the positive productivity effect that represents the main component of the quantity effect, while the activity effect, in the end, appears quantitatively unimportant. Figure 4 then presents the decomposition of the productivity effect and demonstrates that while the technological change effect has been remarkably constant over the entire period, contributing roughly £4,000 annually to profit growth, the technical efficiency effect has been more variable. Further, comparing Figures 2 and 4, we note broad similarities in the way the price and technical efficiency effects evolve over the entire period, with in particular a steady increase over the 1985-1995 period followed by a sharp decline. This suggests that farmers, when facing favourable prices, tend to take more care in managing their crops than when prices are depressed. Figure 5 breaks down the activity effect and shows that the scale effect remains relatively constant throughout the period and contributes negatively to profit growth by £1,000 annually. This effect occurs in a context of concentration of the sector as indicated by a steady increase in the average farm size over time within our sample[vi]. Our results therefore suggest that, somewhat unexpectedly, the exploitation of (assumed) economies of scale does not represent an effective means of maintaining farm profitability in the cereal sector. Finally, we note that the resource mix and product mix effects follow the same pattern over time, and, while the two effects contribute positively to profit growth through most of the period, none of the effect dominates the other. Altogether, there is limited evidence that farmers, by switching production from cereals to other crops, managed to increase profits in a sustainable manner over the period considered.

To summarise, the analysis shows that the overall negative profit change for this sample is largely driven by a large negative price effect, averaging £7,200 per year between 1982 and 2000. This negative price effect is to some extent offset by a positive quantity effect (averaging about £2,800), which is composed of positive productivity and activity effects. The positive productivity effect is driven by the consistently positive effect of technical change on profits while technical efficiency effects have been generally negative. The scale component of the activity effect is predominantly negative whilst this is more or less offset by chiefly positive resource and product mix effects.

VI. Discussion and conclusions

That output price should play such an important role in determining the profit levels of cereals farms is probably an unsurprising conclusion to draw from the results presented in the previous section. The analysis clearly shows that negative price effects largely account for the overall negative profit change that cereal farms have experienced over this period. Year on year changes in profit from 1995 onwards have been particularly heavily impacted by policy change that has occurred since 1993 with the introduction of direct payments to farmers (the Arable Area Payments Scheme), the resulting fall in market prices for cereals and also by the relative strength of sterling during this period.

What is perhaps more unexpected is the relative size of the quantity effect on total profit and the magnitude and direction of the various elements of this effect. The consistent, positive technical change effect is the most important element of the overall quantity effect on profit change. This implies that the best practice farms within the sample have consistently driven the production possibility frontier outwards with consequent positive effects on profit. Conversely, the analysis shows that technical efficiency has, on average, had a negative effect on profit change implying that those farms not on the best practice frontier are falling further behind. However, it should also be noted that the analysis used here is of a deterministic nature and cannot account for factors outside of the control of the farm, such as climatic variation. Given the effect of climate on cereal yield, much of the variation the analysis detects in technical efficiency might be attributable to this.

The activity effect also contributes to the positive nature of the overall quantity effect, although to a lesser extent. This is mostly due to a generally positive resource mix effect. Since this effect measures the allocative efficiency of input use then increased efficiency in this sense would seem to be a rational response to deteriorating output prices. There is also a smaller, but also generally positive product mix effect. Again, substitution away from cereals to other arable crops in response to relative output prices or changes in the policy environment would represent a rational response to changes in cereal prices. Positive resource and product mix effects were partially offset by (almost) consistently negative scale effects. However, the analysis does not enable us to categorically state that this indicates the presence of decreasing returns to scale for this sample, but it does coincide with similar evidence found for a sample of UK cereal farms reported in Department for Environment, Food and Rural Affairs (2003).

This paper uses the profit decomposition method developed by Grifell-Tatjé and Lovell (1999) to analyse the profit levels of a sample of UK cereal farms for the period between 1982 and 2000. Over this period the analysis shows the decline in profit levels that the sample exhibits can be mostly attributed to falling cereal prices, which in the later years of the period studied are due to CAP reform. Cereal prices are, however, outside of the control of the farmer whilst aspects of production relating to technical efficiency, technical change, scale of operation and scope are factors the farmer can influence to a greater or lesser extent. The analysis demonstrates that most of these controllable factors have contributed positively to profit change for this sample (except for technical efficiency and scale) and of these technical change has played the most important role.

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Table 1: Summary statistics for sample 1982 – 2000

		Mean	Standard Deviation	Minimum	Maximum
	Operating profit (£)	-10250.13	55614.78	-726984.00	338541.00
y1	Cereal output (tonnes)	898.10	798.56	0.00	6747.80
p1	Cereal price (£)	118.00	17.31	0.00	215.80
y2	Other crops output (tonnes)	301.78	647.87	0.00	13363.20
p2	Other crops price (£)	183.75	543.26	0.00	25960.00
x1	Family/managerial labour (hours)	2040.49	1366.85	0.00	8400.00
w1	Price of family/managerial labour (£)	3.60	2.10	0.00	10.48
x2	Hired labour (hours)	3367.20	4938.12	0.00	70474.00
w2	Price of hired labour (£)	3.79	2.34	0.00	12.64
x3	Land area (hectares)	184.51	159.19	7.89	1393.10
w3	Rental price of land (£)	128.57	33.49	45.52	394.96
x4	Quantity of variable inputs (index)	66578.76	57136.62	4319.75	560832.70
w4	Price of variable inputs (index)	1.04	0.16	0.77	1.26
x5	Quantity of capital (index)	34589.37	33327.63	1476.44	335184.16
w5	Price of capital (index)	1.04	0.22	0.63	1.33
	Number of farms	436			
	Number of observations	2938			

Figure 1: Annual mean operating profit English and Welsh Cereal Farms 1982 - 2000

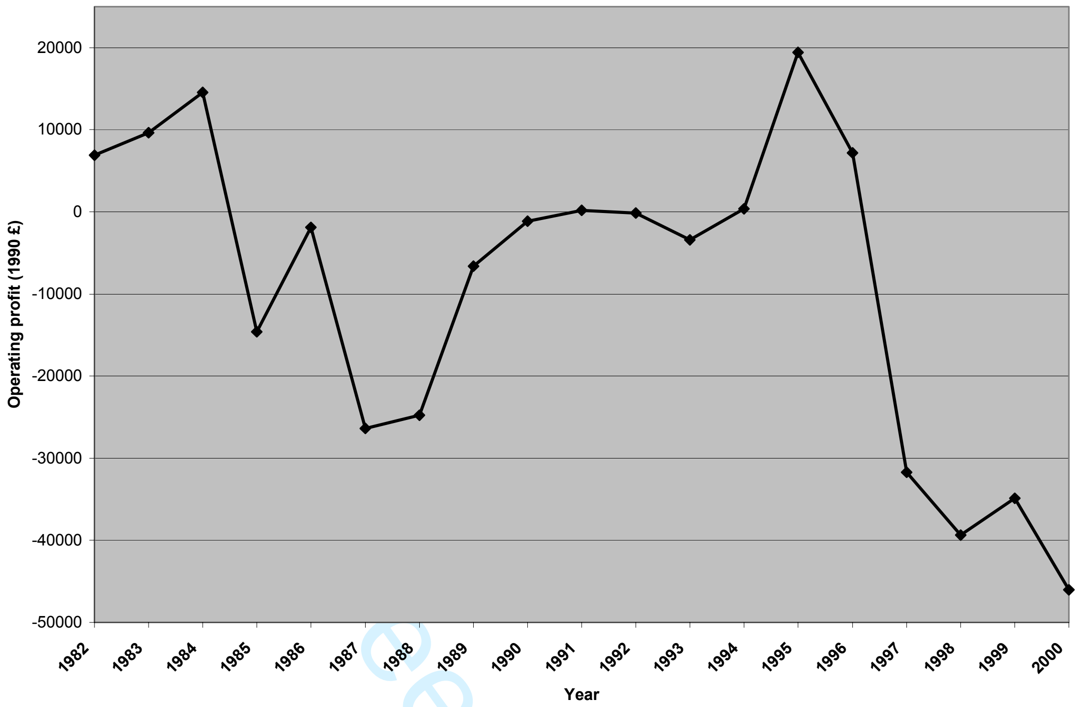

Figure 2: Decomposition of the cumulative profit change

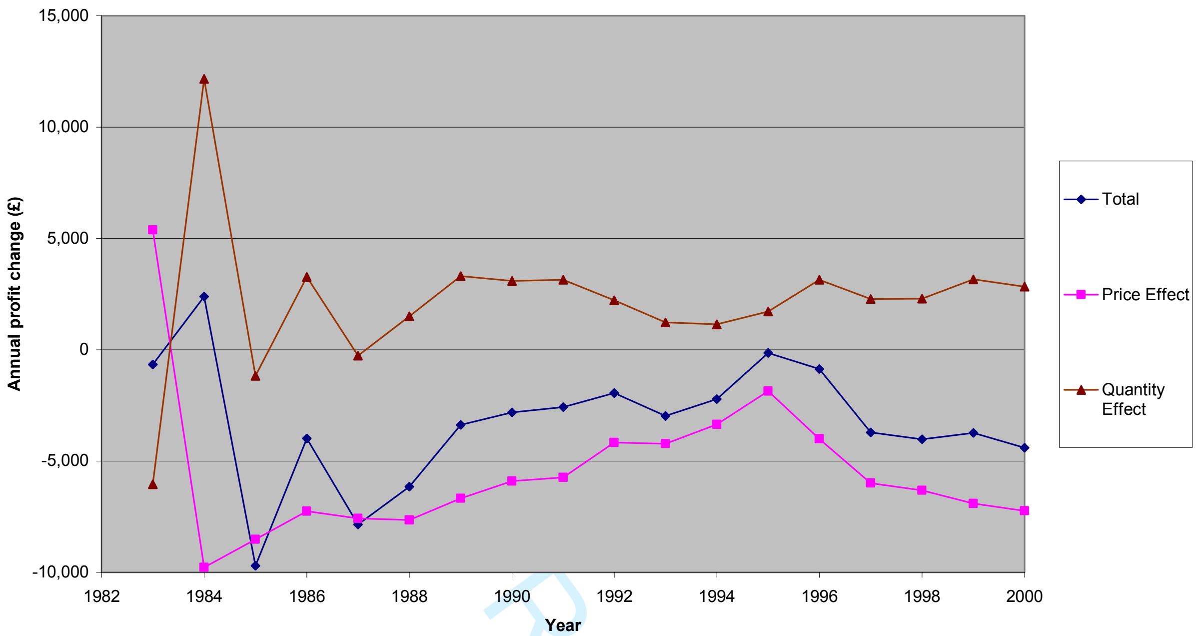

Figure 3: Decomposition of the (cumulative) quantity effect

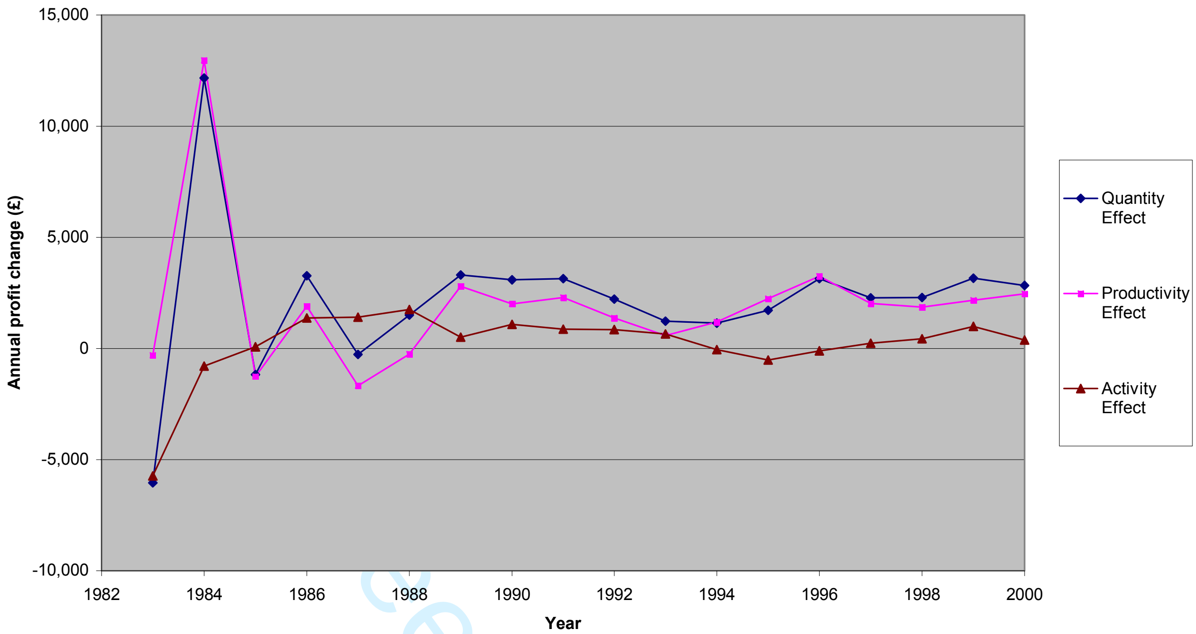

Figure 4: Decomposition of the (cumulative) productivity effect

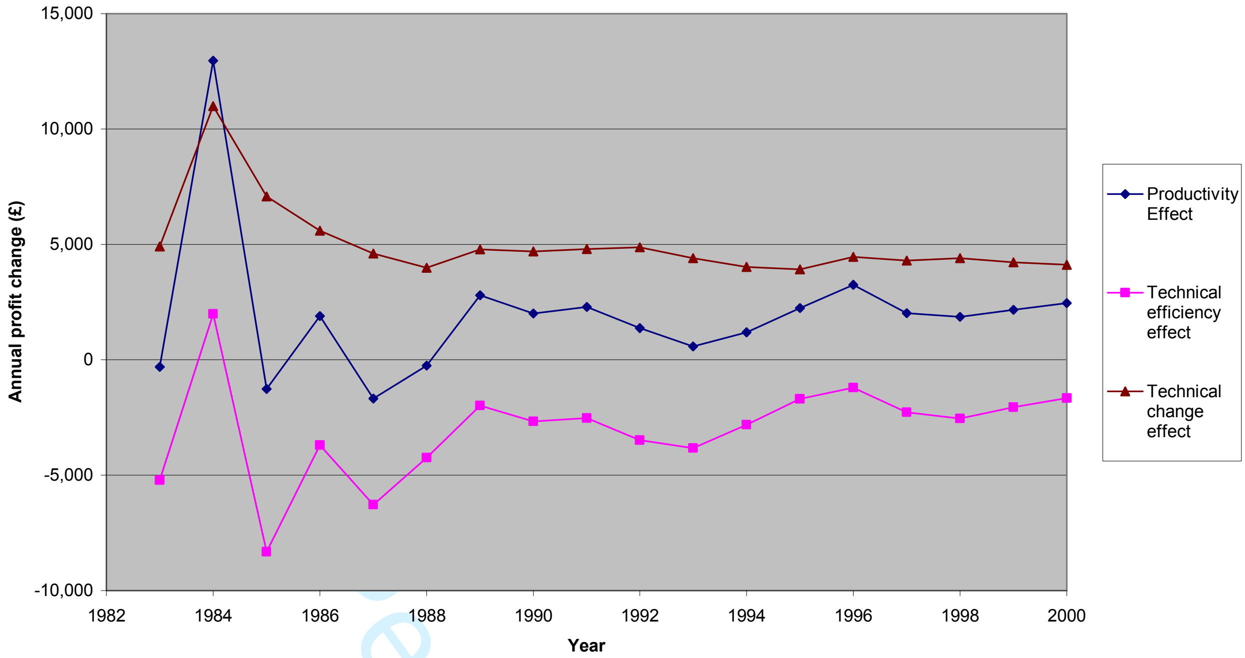

Figure 5: Decomposition of the (cumulative) activity effect

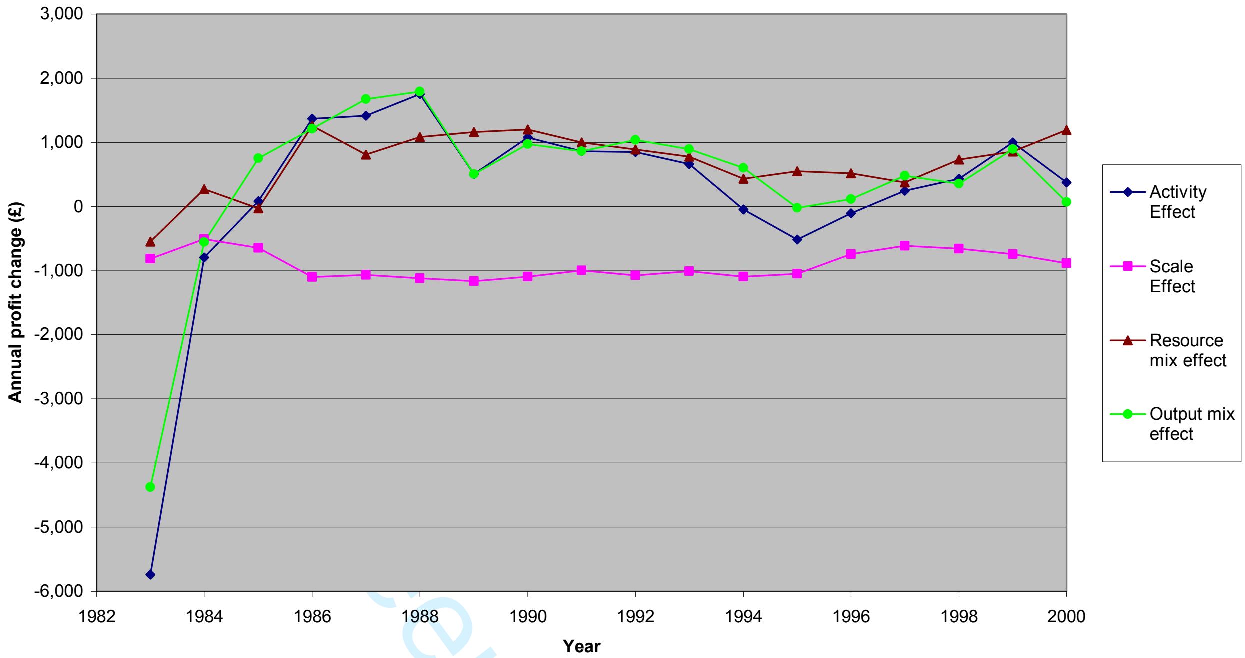

Table 2: Profit Change Decomposition for English and Welsh Cereal Farms 1982-2000 – Average annual changes (£)

Period	*PROFIT CHANGE*										*Number of observations* (i.e., profit changes)
	Total	*PRICE*	*QUANTITY*								
			Total	*Productivity*			*Activity*				
				Total	*Technical Efficiency*	*Technical Change*	*Total*	*Scale*	*Resource Mix*	*Product Mix*	
1982-1983	-668	5,380	-6,048	-305	-5,223	4,918	-5,743	-816	-551	-4,376	111
1983-1984	4,898	-22,257	27,155	23,878	7,897	15,982	3,276	-261	949	2,588	135
1984-1985	-31,261	-6,284	-24,977	-26,615	-26,691	76	1,639	-885	-563	3,086	138
1985-1986	12,877	-3,506	16,384	11,210	9,939	1,271	5,174	-2,446	5,048	2,572	130
1986-1987	-24,982	-9,063	-15,919	-17,549	-17,719	170	1,630	-918	-1,155	3,704	116
1987-1988	3,963	-8,065	12,028	8,285	7,902	383	3,743	-1,417	2,678	2,481	106
1988-1989	14,407	-407	14,814	22,280	12,405	9,876	-7,467	-1,456	1,684	-7,695	115
1989-1990	1,842	551	1,291	-4,517	-8,354	3,837	5,807	-502	1,493	4,817	103
1990-1991	-794	-4,445	3,650	4,459	-1,260	5,719	-809	-256	-569	16	122
1991-1992	3,275	8,601	-5,326	-6,053	-11,490	5,437	727	-1,719	12	2,433	131
1992-1993	-11,370	-4,565	-6,804	-5,913	-6,487	574	-891	-476	-155	-260	149
1993-1994	4,397	4,070	328	6,528	5,844	685	-6,200	-1,794	-2,518	-1,888	156
1994-1995	19,955	12,715	7,240	12,296	9,283	3,013	-5,056	-624	1,653	-6,085	156
1995-1996	-8,249	-26,005	17,757	13,651	3,671	9,980	4,105	2,379	194	1,533	162
1996-1997	-34,084	-27,166	-6,918	-10,904	-13,420	2,515	3,986	753	-1,127	4,361	172
1997-1998	-7,554	-10,090	2,536	-42	-5,755	5,712	2,578	-1,197	4,848	-1,072	174
1998-1999	-231	-14,266	14,034	5,894	4,012	1,882	8,140	-1,801	2,364	7,577	174
1999-2000	-14,586	-12,295	-2,291	7,010	4,508	2,502	-9,301	-3,101	6,405	-12,605	152
Average 1982-2000	-4,404	-7,233	2,829	2,454	-1,660	4,114	375	-889	1,192	72	2,502

Table 3: Profit Change Decomposition for English and Welsh Cereal Farms 1982-2000 – Cumulative changes (£) expressed on a per annum basis

Period	*PROFIT CHANGE*										*Number of cumulative observations*
	Total	*PRICE*	*QUANTITY*								
			Total	*Productivity*			*Activity*				
1982 to:				*Total*	*Technical Efficiency*	*Technical Change*	*Total*	*Scale*	*Resource Mix*	*Product Mix*	
1983	-668	5,380	-6,048	-305	-5,223	4,918	-5,743	-816	-551	-4,376	111
1984	2,387	-9,786	12,173	12,966	1,977	10,989	-793	-511	272	-554	246
1985	-9,705	-8,528	-1,178	-1,258	-8,326	7,068	81	-646	-28	754	384
1986	-3,994	-7,258	3,264	1,895	-3,706	5,601	1,369	-1,101	1,256	1,214	514
1987	-7,858	-7,590	-268	-1,685	-6,286	4,601	1,417	-1,067	812	1,672	630
1988	-6,156	-7,658	1,503	-249	-4,243	3,994	1,752	-1,118	1,081	1,789	736
1989	-3,377	-6,678	3,301	2,795	-1,993	4,789	506	-1,163	1,162	507	851
1990	-2,814	-5,898	3,084	2,006	-2,680	4,686	1,078	-1,092	1,198	973	954
1991	-2,585	-5,733	3,149	2,284	-2,519	4,803	864	-997	998	864	1,076
1992	-1,949	-4,177	2,229	1,379	-3,493	4,872	850	-1,076	891	1,034	1,207
1993	-2,984	-4,220	1,236	578	-3,822	4,400	658	-1,010	776	892	1,356
1994	-2,222	-3,365	1,142	1,192	-2,824	4,016	-49	-1,091	436	605	1,512
1995	-148	-1,861	1,713	2,230	-1,692	3,922	-518	-1,047	550	-20	1,668
1996	-865	-3,998	3,133	3,241	-1,217	4,459	-108	-744	518	117	1,830
1997	-3,719	-5,989	2,269	2,026	-2,266	4,292	243	-615	377	482	2,002
1998	-4,026	-6,317	2,291	1,861	-2,545	4,405	430	-662	734	357	2,176
1999	-3,745	-6,905	3,160	2,159	-2,059	4,218	1,001	-746	855	892	2,350
2000	-4,404	-7,233	2,829	2,454	-1,660	4,114	375	-889	1,192	72	2,502

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[i] For an example of this approach, see Coelli, Rahman and Thirtle (2002).
[ii] The well-known Malmquist productivity index relies on the same idea.
[iii] Note that we estimate VRS models. The corresponding CRS models, which are more restrictive, are easily obtained by removing the constraint $1^{v}.\lambda = 1$.
[iv] The linear programming problems were solved using the Mathematica software, which took roughly four hours on an ordinary PC. The codes are available from the authors upon request.
[v] The difference is explained by the fact that the average profit depicted in Figure 1 is calculated over different sub-samples of farms in each year, while the profit changes reported in Tables 2 and 3 are calculated only for those farms that are present in consecutive periods.
[vi] Total land area, per farm, increased from an average 154 ha in 1982 to 211 ha in 2000.