A Comparison of Agricultural Production on the Estates of King, Church and Laity in 1086

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Flinders Business School Research Paper Series

07-08

ISSN 1441-3906

Summary:

This paper uses data collected in the Domesday Survey of 1086 to compare agricultural production on the estates of king, church and laity. I examine whether similar production functions describe production on the three major classes of production unit and use DEA frontier methods to assess whether one class of estate was more efficiently worked than another.

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Acknowledgement:
I would like to thank Eva Aker and Beverley Vickers for their excellent research assistance, S. Snap, M. Muggles and C. Plus for their caring assistance, colleagues and seminar participants for their comments and The Australian Research Council and the Flinders University for financial support.

Keywords: Domesday Book, DEA, production functions, manorial efficiency.

1. Introduction

In the late eleventh century, the principal economic activity was agricultural production on the estate or manor. The lord of the estate, through his manager or bailiff, employed the residential labour force and resources available on the estate to produce arable and livestock produce. The institutions of feudalism and manorialism discouraged trading in land and labour inputs, but there were flourishing local, regional and international markets in outputs. Given these institutions and the infrastructure, one might expect lords to have used the available estate resources to maximise the value of net estate output and then trade to a consumption optimum.

There were three kinds or classes of estate, king's, ecclesiastical and lay. Lay lords derived most of their income from their estates. With this income they fed and housed family members, financed their feudal obligations, purchasing military hardware, chain-mail armour, weapons and stallions for battle, paid the geld and other taxes and engaged in competition with peers in ambitious building programs. One can imagine there was never enough money to go round! Lay lords had strong incentives to run their estates efficiently and maximise estate net income.

Many ecclesiastical lords were no less worldly. Some were major magnates such as bishops. Others, such as priests, ran smallholdings. Although there were doubtless many examples of pious ecclesiastical lords, others behaved in a similar fashion to lay lords, feasting, fighting in battle and indulging self-interest. Some estates were attached to and financed cathedrals and churches monasteries and nunneries. Campbell (1995, p188) argues that, with the advantage of a knowledge base, some ecclesiastical estates were leaders in technological and commercialisation in the twelfth and thirteenth centuries. Were ecclesiastical estates also leaders in agricultural practice and efficiency in the late eleventh century?

There were also many estates held directly by the king, but not directly managed by him. Usually, the king's estates were run by the sheriff, the king's agent in the county. One might expect the sheriff to have less incentive to work these estates efficiently than his own, unless, of course, he wished to impress the king. Were lay estates more efficiently worked than those of the king?[1]

It is quite remarkable that we can seriously investigate the question of the relative efficiency of the three classes of estate, not by searching, as historians often do, for evidence in contemporary or near contemporary documents, or by examining in minute detail the fragmentary records of one or two estates, but by examining the evidence relating to most estates in the country. The record of the Domesday Survey of 1086 provides this information. The survey data were carefully collected

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[1] Postan (1966, Ch. 6) describes estate institutional structures.

and compare favourably with production unit data collected today. The quality of the data demands the use of appropriate econometric technology for their analysis. In this paper, I estimate production functions and use frontier (DEA) methods to address the issue of the relative efficiency in production of king's, ecclesiastical and lay estates in 1086. The study is based on data relating to more than 750 estates in the County of Essex .

In the next section, I describe the Essex Domesday data. The econometric analysis follows. This is in two parts. First the average estate production relationship in Essex is analysed by estimating constant elasticity of substitution (CES) production functions, to see if similar functions describe production on the three classes of estate. In the following sub-section, DEA is used to calculate efficiency measures for all estates in the Essex sample and regression methods employed to establish whether, after controlling for factors that could have affected efficiency, one class of estate was, on average, more efficiently worked. There is a short concluding section.[2]

2. The Data

The Domesday Survey was carried out in about 20 months from Christmas 1085 till the death of King William (the Conqueror) in 1087. This was some 20 years after William, as Duke of Normandy and claimant to the English throne, invaded England. By the time of the Survey, the English had been pacified and land was in the hands of the Normans and their allies.

The Survey was organised by dividing England into seven circuits, each with a team of commissioners, who sent out questionnaires to landholders and tested their responses in public in local courts. County returns were compiled and then assembled to form a circuit return, which was sent to the Exchequer at Winchester. Six of the circuit returns were edited into a document now known as Great or Exchequer Domesday Book and the return from circuit VII, consisting of Essex, Suffolk and Norfolk, forms Little Domesday Book.

There were a number of safeguards to ensure reliable information was collected. To ensure that circuit commissioners were not tempted by self-interest but acted unbiasedly, they were chosen so that they held little land in the counties of the circuit, questionnaire answers were verified in public in the county court by landholders from the same hundred acting under oath, and the whole process was monitored by agents of the king.

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[2] A number of historians have examined the productivity of medieval English agriculture. These studies involved comparing ratios of output to an input such as land area or number of workers. None have used frontier methods, estimated production functions or used statistical methods, such as regression analysis or even statistical testing. Some of the more interesting studies that relate to an era close to 1086 are Campbell (2000), Karakacilli (2004), Titow (2004) and Thornton (1991, 2003).

Domesday Book was written in Latin, but excellent English translations (such as Victoria History of Essex, 1977, the so-called Phillimore edition, Morris (1975) and the Alecto Historical Editions translation, Williams and Martin, 2003) are available. A typical estate entry lists the resources on the estate in 1086, the manorial net output and income (referred to as the 'annual value') and the tax assessment. Often there are also data relating to 1066 and sometimes for an intermediate year, but this analysis only considers the more comprehensive 1086 data. Although there are some ambiguities, for the most part the entries are readily interpreted.

An example of an entry is that for Blunts Hall in the Hundred of Witham, Essex. Blunts Hall is listed in Domesday Book as an estate of Count Eustace of Boulogne, a major Norman magnate holding many estates in Essex and throughout England. The Victoria County History of Essex English translation of the entry (Vol. 1, p.462) reads,

"BLUNDESHALA [Blunts Hall], which was held in King Edward's time by 1 free woman as 1 manor and (as) half a hide, is held by the count in demesne."

This means that the estate was held in 1066 (King Edward's time) by a free woman (although it is unusual, there are a few other cases of women holding land), the tax assessment was half a hide, but at the time of the Survey (1086) the estate was held and managed on behalf of the Count. There were no sub-tenants. The entry continues,

"Then as now (*semper*) 1 plough on the demesne and 1 bordar. (There are) 6 acres of meadow. It was then worth 20 shillings; now 10."

This indicates that the resources available to run the estate in 1066 and 1086 consisted of 1 ploughteam, 1 bordar (a bonded peasant) and 6 acres of meadowland. The net income or annual value of the manor was 20 shillings in 1066 and 10 shillings in 1086.

Essex data were chosen for the study because, being part of Little Domesday, they are more comprehensive and detailed than for most other counties and more easily interpreted than Suffolk and Norfolk data (the other counties in Little Domesday).[3] The production analysis is restricted to

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[3] For further background information on Domesday England see McDonald and Snooks (1986, Chs. 1 and 2, 1985a, 1985b, 1987a, 1987b) and McDonald (1998). More comprehensive accounts of the history of the period can be found in many works including Brown (1984), Clanchy (1983), Loyn (1981, 1983), Stenton (1975), and Stenton (1951). Other useful references include Ballard (1906), Darby (1952 and 1977), Galbraith (1961), Hollister (1956), Lennard (1959), Maitland (1897), Miller and Hatcher (1978), Postan (1966, 1972), Round 1895, 1903), Aston (1987), Holt (1987), Hallam (1988), the articles in Williams (1987) and Britnell and Campbell (1995), especially that of Snooks, and references cited in McDonald and Snooks (1986). For more on the Survey see McDonald and Snooks (1986, Sec.2.2), references cited there, and the articles in Williams (1987). For a comparison of the Domesday and modern surveys see McDonald and Snooks (1987c). Domesday Book derives its name from its role as an instrument for settling land disputes. After William's

the 763 holdings for which information appears to be complete.[4] Figure 1 contains box plots of the net incomes or annual values of the three classes of holding. The plots display the main features of the annual value distributions (minimum and maximum values and the first three quartiles). They indicate that the king's estates were, on average, larger economic units than ecclesiastical estates, which in turn were larger than lay estates. The king's estates' distribution also displays greater dispersion than the others. Table 1 lists the main resources of the estates.[5]

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death, in land disputes, there was no appeal beyond Domesday Book, the book of last judgement. Land rights could be traced to Domesday Book but no earlier.

[4] The data file was compiled directly from Domesday Book entries in the Victoria History of Essex (1977) which were checked against a facsimile of the Latin transcript and an English translation in the Phillimore edition and the Alecto Historical Editions translation. By my count there were a total of 925 holdings in Essex (48 king's estates, 182 ecclesiastical and 695 lay). Of the 925 Essex holdings, information appears incomplete for 24 king's, 20 ecclesiastical and 186 lay estates. This may seem to be a large number, but they are mainly small estates and account for less than three percent of the recorded county estate total annual value. For a few estates, the value is not recorded (three king's estates, two ecclesiastical and 13 lay) and, for others, it is unclear how production was carried out because no labour is listed (although in some cases it could have been provided by the tenant) or, alternatively, no ploughteams and no livestock listed (21 king's, 18 ecclesiastical and 98 lay estates). A further five lay estate entries appear implausible and two more could not be located geographically. The king's entries are usually longer, more complex and involve more holdings than the ecclesiastical and lay entries. Often there is one main estate and several satellite smallholdings. Many of the latter were held by Harold in 1066, and by 1086 had passed to lay or ecclesiastical lords. An example is the Lawford entry, which contains information on one large estate still held by the king in 1086 and six or more smaller holdings no longer in the king's hands in 1086, (Victoria History of Essex, 1977, pp. 434-5). Some of the larger ecclesiastical entries also involve several holdings, with the land held in both 1066 and 1086.

[5] The main estate resources were ploughteams, livestock, labour and land. Demesne ploughteams were only used on the demesne. Peasants' ploughteams cultivated the peasant plots but also worked the demesne land when the peasants worked for the lord. All livestock, other than horses, were combined into one variable, using market values. The weights for livestock were: cows, 24; swine, 8; sheep, 5; and goats, 4. Sources for underlying market prices include Maitland (1897, p. 44), Ballard (1906, p. 27), Round (1895, p. 367) and Raftis (1957, p. 62). Horses were excluded because they were used largely for non-productive military and leisure purposes. It was not until the thirteenth and fourteenth centuries that ploughing with horses became common. Horses cost more to keep than oxen because of the cost of shoeing and the need to feed them oats in winter, whereas oxen could survive on hedge clippings, see Postan (1966, p. 80), Hallam (1981, p. 54) and Langdon (1982). The main categories of labour were the more free freemen and sokemen, who usually held less onerous labour obligations to the lord, bonded peasants, mainly villans (or villeins) and bordars in Essex, and slaves (or serfs), the latter often being associated with the ploughteams. The main land categories were woodland, meadowland and pasture, In addition, there were minor resources, such as vineyards, beehives and saltpans. Estimates reported in McDonald and Snooks (1986, pp.119-130) suggest these made only a minor contribution to estate production. As labour was tied to an

3. The Analysis

3.1 The Average Relationship

The average production relationship was analysed by estimating constant elasticity of substitution (CES) production functions describing estate production. Estimates were obtained by employing a nonlinear least squares procedure, which exploits a link between the Box-Cox class of functions and the CES function.[6]

The first two panels of Table 2 exhibit CES production function estimates for the ecclesiastical and lay estates, and panel 3 gives p-values for tests that corresponding coefficients are equal (as against the alternative they are not).[7] Corresponding coefficient estimates are similar and the p-values are well above conventional significance levels, strongly supporting the null that corresponding coefficients are equal. The joint test that corresponding a, b, g and h production function coefficients are equal had a p-value of .528.

As there are only 24 king's estates, it is not sensible to estimate a production function for these estates alone. Instead I asked if the 24 observations could be regarded as 'being generated by', or consistent with, a CES function estimated from both the ecclesiastical and lay observations (with

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estate and generally there was little input trading but considerable trading in outputs, estate production can be characterized as transforming an essentially fixed set of inputs into outputs which were then traded to meet the lord's consumption needs, see McDonald and Snooks (1985b, pp.98-100) and McDonald (1998, pp.11-12).

[6] Briefly, the Box-Cox relationship between annual value (V) and, for simplicity, a single resource, R, can be expressed as $(V^{a/b}-1)/(a/b) = d+e(R^{a}-1)/a+f$, where a, b, d and e are parameters and f is a random disturbance. This can be re-expressed as a CES function, $V = (g+hR^{a}+f^{*})^{b/a}$, where $g = 1+(ad)/b-e/b$, $h = e/b$ and $f^{*} = (af)/b$. The CES function is highly nonlinear in the parameters, and in these circumstances it is essential to find good starting values for the iterative estimation procedure. These can be obtained from the Box-Cox relationship by carrying out a grid search of values for a and b and least squares estimation of d and e for each pair of values. Having found good starting values, nonlinear least squares (allowing for the Jacobian of the transformation, see Box and Cox (1964), was then used to estimate the CES function parameters a, b, g and h. A detailed description of the method is given in McDonald and Snooks (1986, p.162-76 and 217-27) and McDonald (1998, p.119).

[7] A battery of tests indicate no heteroskedasticity in the disturbances. The test that the disturbance variance in the ecclesiastical and lay functions were equal was based on an obvious extension of the Goldfeld-Quandt test, Goldfeld and Quandt (1965), to nonlinear situations. The other tests in row 3 are Wald tests of coefficients in a single equation that allowed for different ecclesiastical and lay coefficients. They were estimated with the LSQ and ANALYZ procedures of TSP, Hall and Cummins (1998).

common ecclesiastical and lay coefficients). When the individual estate observations were tested for consistency with the estimated function, four of the 24 tests had p-values less than .05 (which corresponds to rejection of consistency at the five percent significance level). Two were only slightly below .05 (the p-values were .048 and .046) and two somewhat smaller (.039 and .009). If the king's estate data were generated by this function, we would expect to observe one or two p-values less than .05. A more formal way of testing for overall consistency is to carry out a joint test that all 24 king's estate observations were consistent with the estimated function. This hypothesis was resoundingly accepted. The p-value was .986. [8] [9]

The evidence strongly suggests the same CES function describes production on ecclesiastical, lay and king's estates. Panel 4 of Table 2 displays the coefficient estimates for this function, with p-values (for the test that coefficients are zero, against the alternative that they are not) underneath, followed by output elasticities. Most p-values are zero (to three decimal places). Exceptions are those corresponding to the freer labour, freemen and sokemen, confirming that they held variable and lesser work obligations to the lord, and woodland, which might be expected to contribute in only a minor way to estate net output. The estimated function is non-homogeneous (the parameter g is significantly different from zero). The output elasticities indicate the importance, in particular, of ploughteams (with, as expected, a higher elasticity for demesne ploughteams), bonded peasants and slaves in production. The sum of the output elasticities, 1.16, gives an estimate of returns to scale. This indicates slightly increasing but close to constant returns to scale. The elasticity of substitution estimate is 1/(1-a) = 1.47 (slightly greater than the value of 1.0 for the Cobb-Douglas function), and, in other respects, the estimates indicate plausible properties for the production function.[10]

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[8] The tests are based on the method proposed in another context by Salkever (1976), which I have generalized to nonlinear functions. Basically, the CES production function is estimated using ecclesiastical and king's data and 24 dummy variables, one for each king's estate observation (taking the value one for the king's estate observation; zero, otherwise). In this equation, coefficient estimates for the CES function and the residual sum of squares are the same as in an equation estimated with the ecclesiastical and lay data alone, and testing that the dummy coefficients are zero corresponds to testing that the king's estate data are generated by the CES function.

[9] The estates corresponding to the p-values of .039 and .009 are Shalford in the Hundred of Hinckford and Great Sampford in Freshwell Half-Hundred, respectively. Their annual values were quite large, 440 and 600 shillings, and they were well endowed with resources. In both cases, annual value increased markedly from 1066 to 1086, and, for both, the actual annual value exceeded that predicted by the CES function.

[10] They indicate the resources had positive marginal products, there were diminishing returns to resources, and the marginal product of a resource increased as the level of other resources increased. Also, the isoquants are strictly convex, ensuring diminishing marginal rates of substitution between

3.2 The DEA Analysis

Now I examine whether one category of estate was managed more efficiently than another. Intuitively, it makes more sense to measure efficiency as a percentage of best practice performance rather than relating it to an average performance measure (such as the CES production function). A second advantage of this approach is that the DEA frontier method is a non-parametric method, which does not require the assumption of a particular of functional form. Using linear programming methods, DEA efficiency measures (the ratio of actual to frontier output expressed as a percentage) were estimated for each estate assuming constant returns to scale strong disposability of inputs technology.[11]

These efficiency percentages measure production performance relative to observed best practice. What constitutes best practice will depend on the technology, institutions and infrastructure available to producers, so that if, for example, agricultural methods are improved, the frontier will move outwards. Of course, best practice may not be good practice. It is possible that all production units are badly organized, but if some units are well organized, then we might expect the best practice frontier will approximate good practice.

The efficiency percentages ranged from 10% for a lay estate of Count Alan of Brittany, Little Bentley, in the Hundred of Tendring, worth three shillings, to 100% for 55 estates (that lie on the frontier). The median and mean efficiencies were 49% and 51%, respectively. 25 percent of estates had efficiency percentages greater than 35% and 75 percent greater than 65%.[12]

The estates of the king appear to have been, on average, better managed than the ecclesiastical and lay estates. The mean efficiency for the king's estates was 70% as against 53% for ecclesiastical

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resources, see McDonald and Snooks (1986, Ch. 9), for example, for properties of production functions.

[11] Details of the procedure are described in, for example, McDonald (1996 and 1998, ch. 1-3). Constant returns to scale is *a priori* a plausible assumption because production on both large and small estates usually involved the same activity but in different multiples. For example, arable agriculture on the demesne centred on the use of oxen ploughteams and their complement of manpower. Approximately twice as much land could be ploughed with two ploughteams in a day as with one, thus giving credence to the notion that, roughly speaking, a doubling of inputs resulted in a doubling of output. This reasoning is supported by empirical evidence described in McDonald (1998, p.112). There it is shown that frontiers estimated assuming weaker technological assumptions than constant returns to scale do approximate the constant returns to scale frontier. Production function estimates reported there and in this paper also indicate close to constant returns to scale.

[12] In McDonald (1998, *C*h. 6), efficiency on Domesday estates is compared with production efficiency in more modern eras and it is shown how the efficiency measures can be used as a tool to gain understanding about production on individual estates.

and 51% for lay estates. On the face of it, then, average efficiency levels were very similar on ecclesiastical and lay estates but somewhat higher on king's estates. This assessment, however, does not allow for two important considerations. The first is that the efficiency percentages were calculated under the assumption of constant returns to scale, but there is evidence from the CES production function estimates of slightly increasing returns to scale, and the second is that other factors could have favoured production on the estates. Regression provides a statistical vehicle for investigating these considerations.

If we regress the estate efficiency percentage on two binary variables, a king's estate variable (KBIN, taking the value one, if the estate is a king's estate, zero, otherwise) and a lay estate binary variable (LBIN, analogously defined), we can assess the significance of the differences in the three means. This is because the coefficients on the binary variables are the differences between the king's estates and ecclesiastical estates means and the lay and ecclesiastical estates means. (The intercept is the ecclesiastical estate mean.) The p-values in panel 1 of Table 3 indicate that the first is significantly different from zero but the second is not at the five percent level, and on the joint test that both coefficients are zero (which corresponds to all three means being equal), the null hypothesis is also rejected.

To allow for slightly increasing returns to scale, the estate efficiency percentage was regressed on the two binary variables and the estate's annual value (the best indicator of an estate's economic size). The p-values in panel 2 of Table 3 indicate that the size variable is highly significant. Again, the coefficient on the king's estate binary variable is significantly different from zero at the five percent level and the coefficient on the lay estate variable is not, but now, the hypothesis of equal means is accepted on the joint test.

Finally, the results were controlled for several factors that could have affected efficiency – location within the county, the tenure arrangement and the relative importance of grazing and arable agriculture on the estate. The p-values in panel 3 indicate that, both the location variables (LOC, which indirectly measure the influence of beneficial local production factors, such as advantageous micro-climates and soils, and proximity to market centres, good roads and navigable waterways) and the variable measuring the relative importance of grazing and arable agriculture (GA), were significant factors affecting efficiency.[13] In this equation, the lay estate binary variable coefficient

[13] The estate efficiency percentage was regressed on the king's estate and lay estate binary variables (KBIN and LBIN), 21 county location variables (LOC, binary variables indicating the local area or hundred location), a binary variable indicating whether or not the estate had a sub-tenant (TEN), the estate's annual value (SIZE, which indicates the economic size of the estate) and a variable describing the livestock/arable mix of the estate (GA). This last variable was defined as livestock listed on the estate less cattle and beasts (which were associated with ploughing) divided by the number of ploughteams on the estate. Tests indicated that the regression disturbances were homoskedastic. Estates with a greater grazing emphasis tended to be more efficient. This probably

estimate is very close to zero and the king's estate variable coefficient estimate indicates a difference in king's and ecclesiastical estate means (allowing for the other factors) of 10%. The p-values indicate this difference is significantly non-zero at the five percent level, but the joint test that all three means (king's, ecclesiastical and lay) are equal is accepted at that significance level (but not at the ten percent level).

4. Conclusion

The conclusion is that, when we allow for slightly increasing returns to scale and factors influencing efficiency, mean efficiency was very similar indeed on ecclesiastical and lay estates. There is weak evidence that the king's estates were better managed, but, statistically, at the five percent significance level, we cannot reject the hypothesis of a common efficiency level on ecclesiastical, lay and king's estates. This coupled with the CES production function estimates suggests that, despite differences in the institutional structures of king's, ecclesiastical and lay estates, there was little difference between production processes and management performance on the three classes of estate.

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reflects the profitability of the wool trade. Many sheep were grazed on the Essex marshlands and wool was exported to the Continent.

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Table 1 Main resources of the 763 estates included in the production analysis, Essex, 1086

	King's (24)	estates	Church (162)	estates	Lay (577)	estates
	mean	percentage estates	mean	percentage estates	mean	percentage estates
Annual values	406		143		109	
Demesne ploughteams	2.8	96	2.0	98	1.9	98
Peasants' ploughteams	10.0	75	4.2	65	2.3	63
Livestock	837	54	502	65	543	60
Freemen and sokemen	2.7	29	1.1	11	0.6	12
Bonded peasants	32.1	96	17.7	98	12.1	96
Slaves	5.2	79	2.3	64	2.2	62
Woodland	261	88	162	72	106	74
Meadow	23.2	75	9.4	56	12.2	74
Pasture	53.3	25	59.8	30	28.3	20

Notes: 'percentage estates' is the percentage of estates with some of the resource. Annual values are in shillings. Livestock is a weighted sum of cows, swine, sheep and goats, see note 5. Woodland is measured in terms of the number of swine that could be supported and pasture by the number of sheep that could be supported. Meadow is in acres. The other variables are measured by a count of their number.

Table 2 CES production function estimates, Essex estates, 1086

	Parameters	a	b	g	h_1 pld	h_2 plp	h_3 li	h_4 fs	h_5 bp	h_6 s	h_7 w	h_8 m	h_9 p	σ^2	$\bar{R}^2$	n
1.	Ecclesiastical estates: coefficients	.44	1.61	1.17	.63	.51	.01	.07	.10	.10	.01	.04	.01	865	.898	162
2.	Lay estates: coefficients	.42	1.45	.67	.94	.45	.01	.06	.18	.18	.01	.05	.03	717	.857	577
3.	p-values, testing coefficients equal	.755	.517	.315	.301	.800	.337	.919	.338	.297	.223	.713	.244	.136		
4.	Ecclesiastical, lay and king's estates coefficients	.42	1.56	.85	.76	.44	.01	.03	.14	.14	.01	.05	.02	813	.875	763
	p-values	.000	.000	.000	.000	.000	.000	.193	.000	.000	.076	.000	.000			
	output elasticities				.44	.30	.06	.01	.17	.08	.02	.05	.03			

Notes: The CES production function takes the form $V = (g + h_1 R_1^{a} + \ldots + h_9 R_9^{a} + f^*)^{b/a}$, where V is the estate's annual value or net output and the R_i are the estate's demesne ploughteams (pld), peasants' ploughteams (plp), livestock (li), freemen and sokemen (fs), bonded peasants (bp), slaves (s), woodland (w), meadow (m) and pasture (p), respectively, see note 5. σ^2 is the disturbance variance and $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom.

Table 3 Mean production efficiency on king's, ecclesiastical and lay estates, Essex 1086

1. Unadjusted estimates

Efficiency % = 53.0 + 17.0 KBIN – 1.6 LBIN

p-values: .000 .000 .404 joint test: .000

2. Adjusting for slightly increasing returns to scale

Efficiency % = 49.5 + 10.5 KBIN – 0.8 LBIN + .025 SIZE

p-values: .000 .033 .679 .000 joint test: .057

3. Adjusting for other factors also

Efficiency % = 40.1 + 10.0 KBIN + 0.1 LBIN + .027 SIZE + * LOC + .84 TEN + .0082GA

p-values: .000 .039 .959 .000 .000 .616 .017

joint test: .097

Notes: KBIN and LBIN are binary explanatory variables indicating whether or not the estate is a king's or lay estate, SIZE is the estate's annual value or net output, measuring the economic size of the estate, LOC represents a set of binary variables (each with different coefficient estimates which are not listed) indicating the local area (or hundred) location of the estate (the p-value relates to the joint test that the coefficients are all zero), TEN is a variable indicating whether or not the estate was held in demesne and GA is a variable measuring the relative importance of grazing and arable agriculture on the estate, see text and endnotes for details. The joint test p-value is the p-value for the test that the coefficients on KBIN and LBIN are both zero against the alternative that at least one is different from zero. Tests indicated the regression disturbances were homoskedastic.

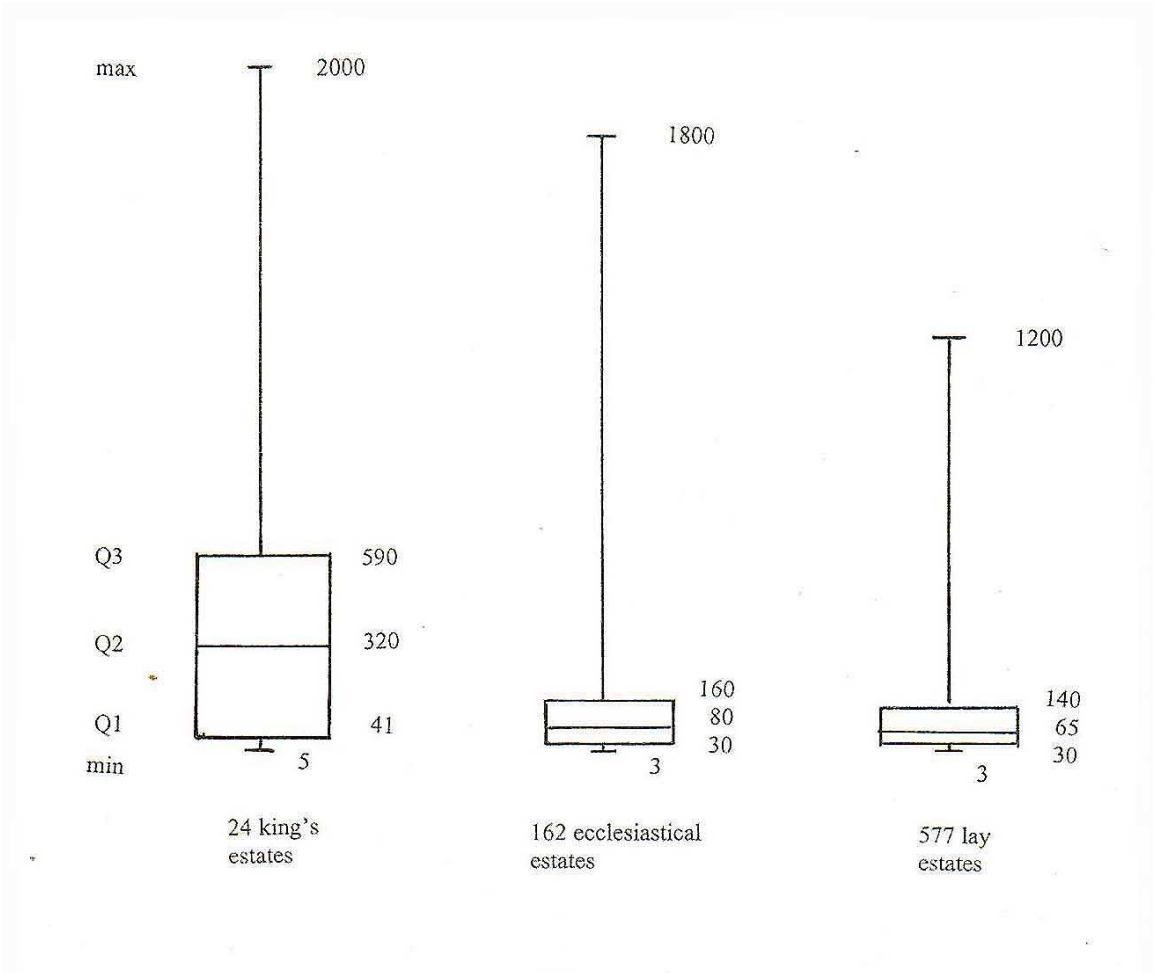

Fig. 1 Box plots of annual values (landholders' net output), Essex estates 1086