EFFICIENCY AND SIZE OF AGRICULTURAL PRODUCTION CAPACITY: A COST ANALYSIS OF DANISH FARMS

by

MOGENS LUND, DORTHE E. PEDERSEN & LARS C.E. HANSEN

Abstract

The aim of this paper is to measure the cost and size efficiency with respect to allocated production capacity in danish agriculture. In this study 98 cash crop farms, 248 dairy farms and 185 pig farms have been investigated.

A linear programming approach has been adopted in order to calculate the different efficiency scores. One main conclusion is that there exists great opportunities for a better cost allocation of the production capacity in Danish agriculture. However, another main conclusion is that differences in the size of farm capacity is not the most significant explanation for inefficiencies in the capacity costs of the farms investigated.

Introduction

In this paper we will consider the issues of efficiency and size with respect to the capacity costs in Danish agriculture. We believe that in the present era of increasing competitive pressure on farm firms, for instance through further economic integration in the EEC and reduction of the international trade barriers through the GATT negotiations, it is pertinent to investigate the potential for a more efficient allocation of the capacity costs as one way to retain farm income.

For the last several decades the capacity costs such as building, equipment and labour costs have increased mainly as a response to technology innovations, declining real prices of agricultural products and government policies. In the same period, however, the main priorities in Danish agriculture have been to achieve a more efficient allocation and utilization of the variable production resources in the sector, i.e. the feeding and chemical costs. This lack of focus is largely what motivate our attempts to throw light on the relationship between size and efficiency in the capacity costs and to discuss some of the implications for farmers, advisors, policy makers and agricultural economists.

The specific issues dealt with in the following are (1) to present a procedure for decomposing the capacity related efficiency problems; (2) to estimate differences in the capacity costs among different farm groups; (3) to estimate the economic gains of an efficient capacity costs organization in the agricultural sector; (4) to compare empirically the potential cost savings due to a better resource allocation within existing farm capacity to the size-induced cost savings; and (5) to discuss economic and policy implications and suggestions for further research.

Theory and estimation procedures

For several reasons the analysis of capacity costs are a priori complicated. One reason is that the capacity costs of the farm business are more inflexible and less reversible than the variable or unit costs of production. Another reason is that besides economic motives, the risk attitude, working requirements and environmental concern of the individual farmer may also gover the size and composition of these costs. A third reason is that for most types of farm firms in Denmark the capacity costs are allocated for all enterprises taken together, which makes it difficult to measure separately the technical and allocative utilization of the individual capacity resources. A final complication has been that the capacity costs in most economic literature are considered synonymous with fixed costs resulting in the widespread interpretation that these costs cannot be altered.

Taking all these problems into account, we have chosen the theory of distance functions as our theoretical model for analysing the allocation of capacity costs. Although the theory was pioneered more than 30 years ago by Farrell, see Farrell (1957), it has until recently been rather unknown in applied production analysis. While neoclassic theory is founded on the production function, the theory of distance functions is rooted in the concept of technology sets. A technology set can be formulated by collecting production and economic data from a sample of comparable decision making units.

This study makes use of two different technology sets, called T^C and T^R as illustrated in figure 1.

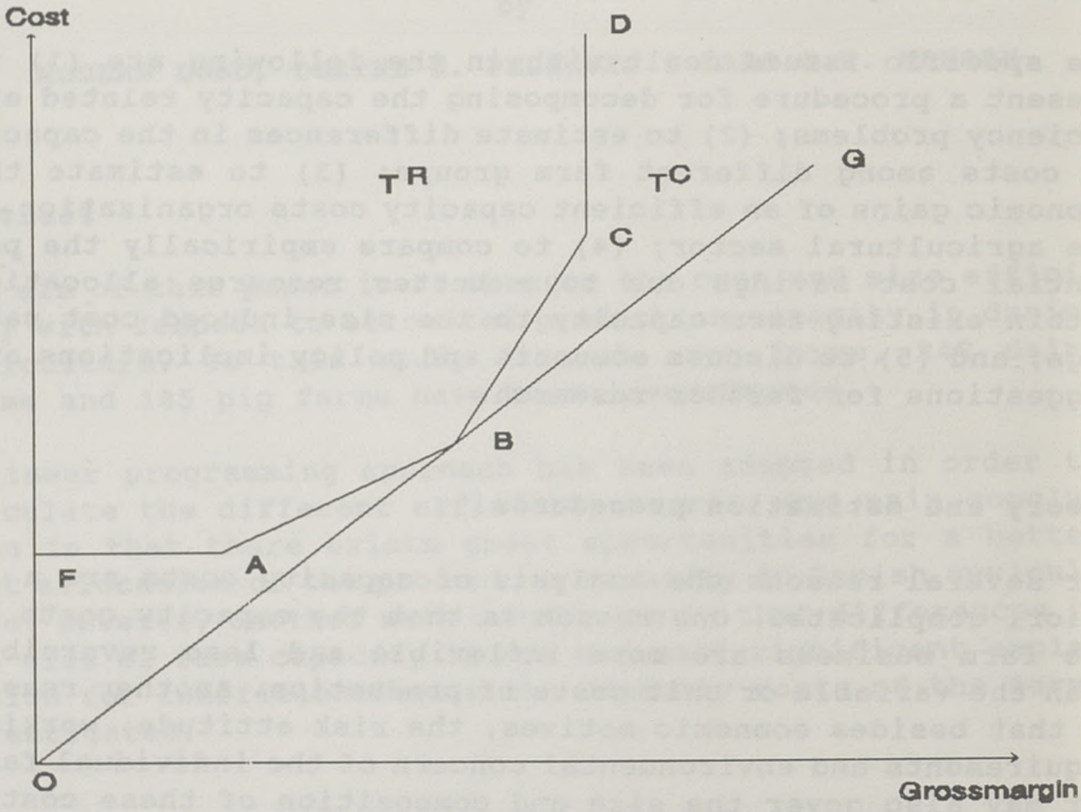

Figure 1. Illustration of the technology sets T^C and T^R

The line OBG and c-axis bounds the technology set T^C from above while the line segments FA, AB, BC and CD together with the c-axis constraints the technology set T^R, again from above. It should be noted that segment AB of technology set T^R exhibits increasing size economies, i.e. declining average costs, whereas segment BC exhibits decreasing size economies, i.e. increasing average costs. Constant size economies is found on line segment OBG because average and marginal costs in this case always will be equal. In figure 1, efficiency may loosely be thought as firms located on the boundary of the technology sets.

An over-all efficiency score, called TOE, can be formulated on the basis of T^C. It is named an over-all efficiency score because it captures both size inefficiency as well as cost inefficiency. As an example, consider farm unit I in figure 2. The farm unit is located inside the technology sets T^C and T^R implying that it is considered inefficient. Thus, for this unit the TOE score can be found as the ratio PN/PI where PN and PI are geometric measured distances.

The technology set T^R has been utilized to formulate a cost efficiency measurement OE; OE measures the degree of cost efficiency without regard to any cost reductions due to size economies. In figure 2 the OE ratio is measured by PM/PI for unit I.

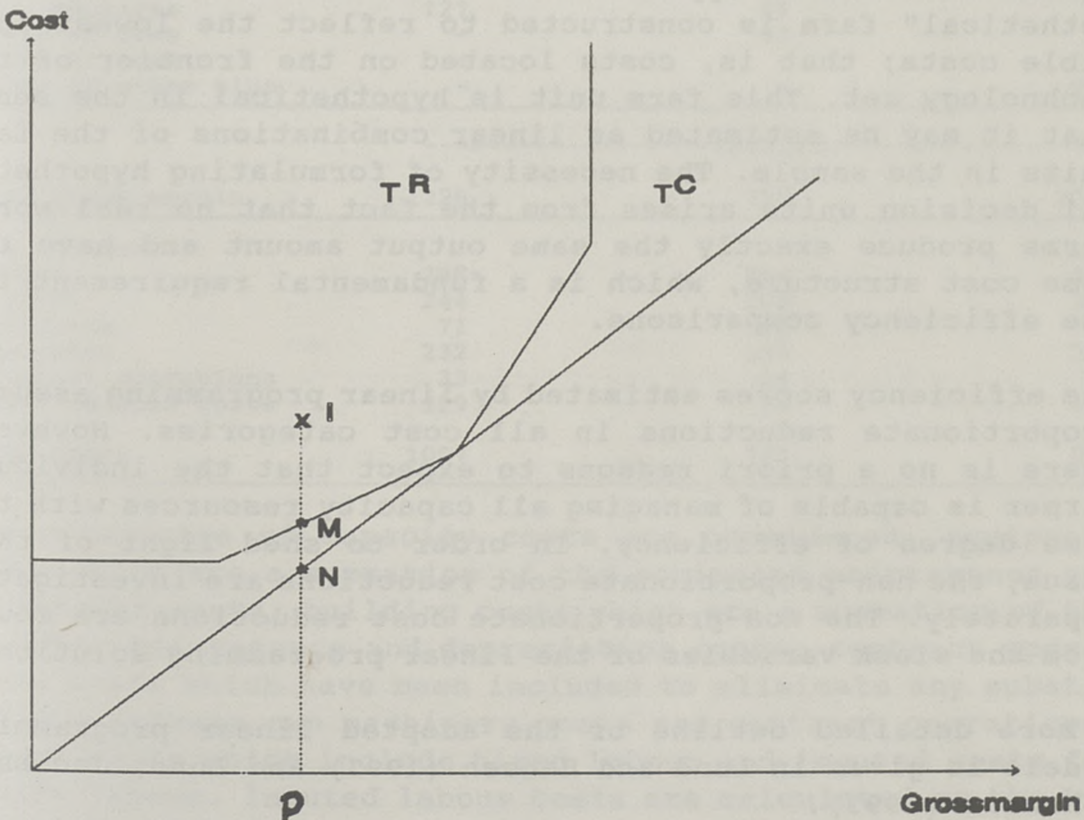

Figure 2. Illustration of the adopted efficiency scores.

Size adjustments to minimize average costs are investigated by formulating a size efficiency score SOE. The SOE score can be found as the ratio PN/PM in the figure where PN stands for the cost located on frontier of T^C and PM measure the cost related to frontier T^R.

By noticing that TOE can be written as:

$$PN/PI\ (TOE) = PM/PI\ (OE) \times PN/PM\ (SOE)$$

it should become apparent that the over-all efficiency measure (TOE) can be interpreted as the simple product of cost efficiency (OE) and size efficiency (SOE).

Linear programming methods have been chosen to calculate the three different efficiency scores for each of the farm units in the sample. Interpreted as an estimation method linear programming is quite different from econometric estimation procedures. Linear programming is used to estimate the distance (i.e. the distance is equivalent to an efficiency score as shown in figure 2) between the costs of the investigated farm and a "hypothetical" constructed farm. The "hypothetical" farm is constructed to reflect the lowest possible costs; that is, costs located on the frontier of the technology set. This farm unit is hypothetical in the sense that it may be estimated as linear combinations of the farm units in the sample. The necessity of formulating hypothetical decision units arises from the fact that no real world farms produce exactly the same output amount and have the same cost structure, which is a fundamental requirement for the efficiency comparisons.

The efficiency scores estimated by linear programming assumes proportionate reductions in all cost categories. However, there is no a priori reasons to expect that the individual farmer is capable of managing all capacity resources with the same degree of efficiency. In order to shed light of this issue, the non-proportionate cost reductions are investigated separately. The non-proportionate cost reductions are found from the slack variables of the linear programming solutions.

A more detailed outline of the adopted linear programming models is given in Lund and Hansen (1993) and Lund, Jacobsen & Hansen (1993).

Data

The data are obtained from the accounting statistics of the Danish Institute of Agricultural Economics. To eliminate the stochastic fluctuations, the data utilized are average figures of the years 1985/86-1989/90. The investigated sample includes 98 cash crop farms, 248 dairy farms and 185 pig farms. Some main statistics for each type of farming are shown in table 1.

All farms are classified as full-time production units according to the standards adopted by the Institute. Realized total gross margin of the farm represents the output-variabel, which means that any inefficiencies in the variable costs are not considered in this study. Total gross margin amounts to at least 350 thousand Danish kroner (T.DKK) for the crop and pig farms and 460 thousand DKK for the dairy farms.

TABLE 1. Summary statistics of gross margin and the capacity costs for the types of farming in the sample.

	Type of farming		
	Cash-crop	Dairy	Pigs
Number of farms	98	248	185
Area, hectares	127	55	58
Number of cows	-	53	-
Number of sows	-	-	93
Number of other pigs	-	-	901
	1000 DKK		
Total gross margin	1225	795	1029
Cost category:			
-Labour	298	294	310
-Capital	244	109	153
-Buildings	71	45	73
-Equipment	232	153	205
-Contract operations	33	54	27
-Miscellaneous costs	129	75	109
Total costs	1007	729	875

Six categories of capacity costs are considered: equipment costs which are a summation of the equipment maintenance and investment costs; building costs which are a summation of the building maintenance and depreciation costs; contract operations costs which have been included to eliminate any substitutions between own machinery costs and contract operations. Labour costs which include hired labour and imputed costs for family labour. Imputed labour costs are calculated on the basis of working hours provided by the farm family multiplied by the wage rate for skilled workers in the manufacturing sector. Capital costs imputed as 4% of the market value of the stock of all production assets. The 4% is a proxy for the opportunity cost of capital measured in real terms. The last cost category is the miscellaneous costs which include energy, utilities, farm insurance and other minor items. Real estate taxes are the only cost item which has been excluded. Except for miscellaneous costs, all other cost categories can be regarded as equivalent to opportunity cost measurements.

The farms in the sample have been divided into five size groups based on a weighted sum of the individual farm's standard gross margins. The standard gross margins are prepared according to the standards used by the EEC-committee of accounting statistics.

Empirical results

Our analyses revealed for all the three types of farming and size classes a significant potential for efficiency improvements. The over-all efficiency scores and the potential cost reductions are presented in table 2. The table shows that the over-all efficiency (TOE) on an average basis in crop farming is 73.2%, in dairy 83.3% and pig farming is 80.9%.

TABLE 2. Over-all efficiency (TOE) and potential cost reductions in crop, dairy and pig production, respectively.

Size class (1000 DKK)	Crop %	Crop T.DKK	Dairy %	Dairy T.DKK	Pig %	Pig T.DKK
350-599	73.2	134.8	83.1	95.4	73.5	125.4
600-799	67.8	203.5	80.3	133.8	76.0	137.7
800-999	72.8	189.9	85.8	116.5	81.1	139.7
1000-1399	71.7	247.0	85.2	153.0	83.1	153.1
1400-	77.7	470.7	93.6	89.9	89.2	143.7
Mean	73.2	259.8	83.3	118.7	80.9	140.5

Analysed by size group, it is seen that the largest farms for all types of farming have the highest over-all efficiency score. The potential total cost saving is nearly 260,000 DKK on average in crop farming, 118,000 DKK in dairy and 140,000 DKK in pig farming. The cost savings in crop production are significantly increasing with increasing size, whereas the cost savings in pig farming are quite similar for all farm sizes.

TABLE 3. Potential cost reductions rising from pure cost (OE) and size (SOE) inefficiencies.

Size class (1000 DKK)	Crop OE	Crop SOE	Dairy OE	Dairy SOE	Pig OE	Pig SOE
	1000 DKK					
350-599	35.0	99.8	56.3	39.1	32.8	92.7
600-799	91.0	112.5	105.0	28.9	62.9	74.8
800-999	115.6	74.3	103.2	13.4	108.3	31.5
1000-1399	203.9	43.1	146.7	6.3	131.6	21.5
1400-	308.4	162.3	58.8	31.0	125.3	18.4
Mean	152.9	106.9	91.2	27.4	92.3	48.2

Decomposition results into cost reductions measured by (OE) and reductions arising from size inefficiencies (SOE) are presented in table 3. The cost reductions in crop and pig farming are in general increasing with size but in dairy farming no similar trend was revealed. Furthermore, the results indicate that the cost reductions due to inoptimal size in general are declining with size for all types of farming. In the light of the EEC milk quota system, it is remarkable that the dairy producers can achieve the smallest gains by optimal size adjustments. A high size efficiency in dairy farming has also been reported by Weersnik et al. (1990).

The most important cost savings are related to reductions in the costs of labour, equipment and capital as shown in table 4. This was to be expected as these cost items cover a major part of the total capacity costs for all types of farming (see table 1).

TABLE 4. Potential cost reductions for each cost category.

Cost category	Crop		Dairy		Pig	
	T.DKK	(%)	T.DKK	(%)	T.DKK	(%)
Labour	77.4	(29.8)	47.5	(39.8)	50.5	(35.9)
Capital	61.8	(23.8)	17.7	(14.9)	25.4	(18.1)
Buildings	18.5	(7.1)	7.3	(6.2)	11.5	(8.2)
Equipment	61.6	(23.7)	24.5	(20.7)	30.9	(22.0)
Contract operat.	7.3	(2.8)	9.2	(7.8)	4.8	(3.4)
Miscellaneous	33.4	(12.9)	12.3	(10.4)	17.4	(12.4)
Total	259.8	(100)	118.5	(100)	140.5	(100)

Cost savings through labour adjustments are most important although they are relative smaller in crop production than in husbandry production. In accordance with the findings of Britton and Hill (1975), it may be suggested that there still can be made improvements in labour utilization in agriculture.

The efficiency results were subjected to various sensitivity analyses. These analyses show that neither changing the data assumptions concerning imputed capital or labour costs nor disregarding a significant number of observations in the sample have any statistical influence on the average efficiency scores reported. For instance, disregarding the 10 farms with lowest average costs for each type of farming, cost efficiency (OE) in table 2 declined by less than 2% in crop farming, 1% in dairy and 3.0% in pig farming. Only for the smallest and the middle size group of crop producers significant efficiency changes were observed.

Assuming that the revealed reductions in capacity costs were achieved, it would cause a major decline in the average costs as illustrated in figure 3.

Without any cost adjustments, the average capacity costs per unit of gross margin are 0.88 DKK in crop farming, 0.94 DKK in dairy and 0.92 DKK in pig farming. Total non-proportionate cost reductions were found to be 89.7, 25.6 and 48.0 thousand DKK in crop, dairy and pig farming, respectively. From figure 3 it is evident that total non-proportionate reductions are equal to the cost reductions due to size adjustments in dairy and pig farming while they are significantly smaller in crop farming. If all cost, size and non-proportionate adjustments have been carried out, the same cost figures could be reduced to 0.67 DKK, 0.78 DKK and 0.76 DKK for the three types of farming. The decline in average costs is increasing with increasing farm size suggesting that the largest farms can achieve the lowest average costs.

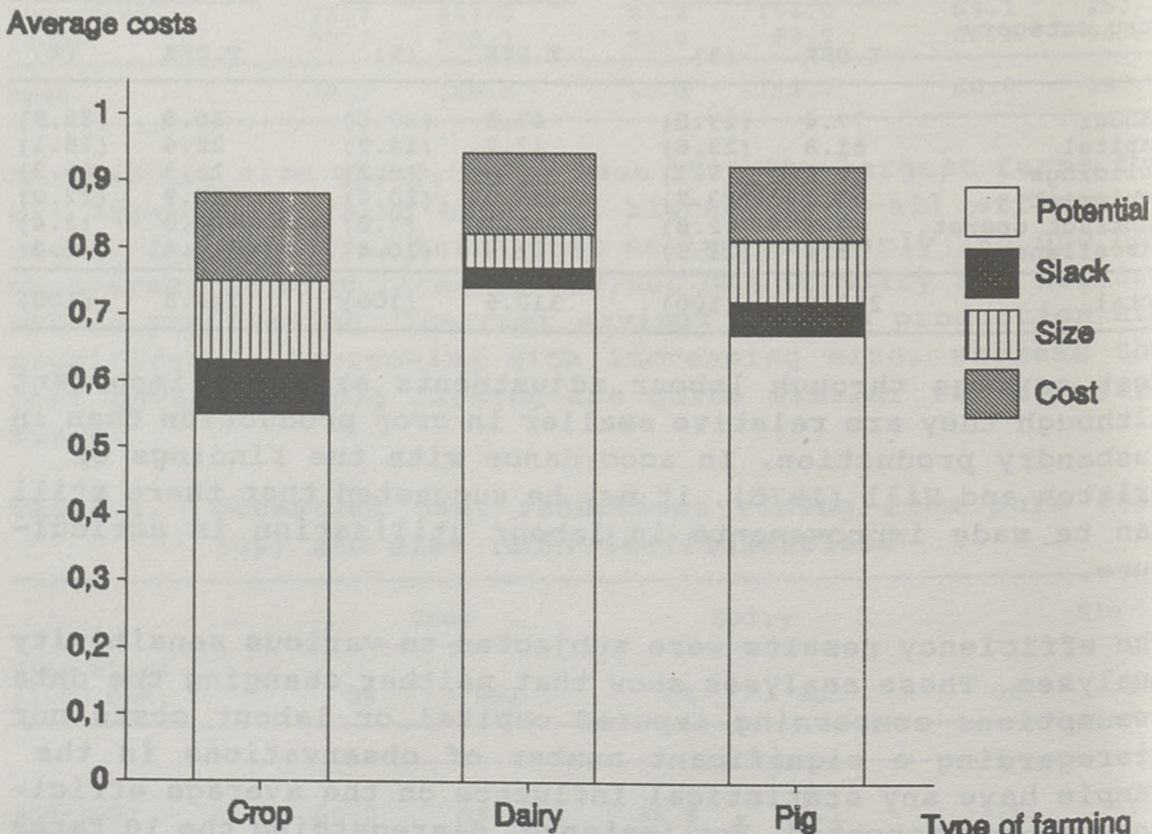

Figure 3. Effects on average costs from pure cost, size and non-proportionate adjustments.

Evidence from table 3 and figure 3 suggest that differences in farm size is not necessarily the most important source of inefficiencies in allocated capacity costs among Danish farms. In fact, a closer examination of the relationship between efficiency and size revealed that average costs for all types of farming can be reduced more by an efficient cost organization within the existing capacity frame than by any size adjustments. Investigated by size class, however, the smallest farms can raise profitability mainly by increasing their size.

Policy implications and needs for further research

The main policy implications of our study are the following: (1) The efficiency methods applied may be helpful to policy makers in analyzing cost performance in the agricultural sector; (2) a variety of specific incentives, i.e. rural policies and extension programs, should be implemented to lower capacity costs among different types of farms; (3) national and EEC price, tax and financing policies should be neutral with respect to farm size; (4) more applied work into the dynamics of capacity adjustments is urgently needed; and (5) improved farmer education and training is needed to increase labour utilization.

The major shortcomings of this study have been the lack of any statistical properties by using linear programming models and the use of aggregated cost data, which makes it impossible to decompose any inefficiencies into their technical and price components. By the same token, the revealed spread in our results may be explained by differences in technologies, objectives and management routines among farmers. Unfortunately, such differences cannot be investigated by the accounting statistics adopted. Without denying the relevance of these and other deficiencies, there is no doubt in our minds that further efficiency studies can improve our understanding of many other issues dealt with in agricultural economics.

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