ECONOMIES OF SIZE IN WHEAT PRODUCTION

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This paper investigates the relationship between the cost of producing wheat and the size of the wheat enterprise on farms in the Boolooroo Shire of New South Wales. The impact of seasonal variation and new technology on the cost/size relationship is also examined. The estimated longrun cost functions suggest that significant cost economies may be achieved as the area sown to wheat on a farm in the region concerned is increased to approximately 1,000 acres.

The total acreage planted to wheat in the Boolooroo Shire trebled during the decade ending in 1968.[1] The Shire is now an important wheat-producing region, despite the fact that it has the disadvantage of having a relatively unreliable rainfall for wheatgrowing. The crops planted in 1965, 1967 and 1968, 3 of the 4 years preceding the introduction of delivery quotas, were all adversely affected by inadequate rainfall during the growing season.[2] The results in this paper relate to two consecutive wheat crops, namely the crop planted in 1966 (the last good season before the introduction of delivery quotas) and the crop planted in 1967 (a year of poor crops).

The data were collected by a farm survey in 1967 and a follow-up mailed questionnaire in 1968. An area sampling procedure was employed using a map showing all the agricultural holdings in the Shire.[3] The original random sample consisted of 104 holdings which represented a sampling fraction of 25 per cent. However, only 51 of these holdings were studied

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[1] The Boolooroo Shire is located on the North Central Plain of New South Wales extending from east of Bellata to the Queensland border, a distance of approximately 120 miles.

[2] A large proportion of the crops planted in the Boolooroo Shire during 1965 were complete failures. Yields in the 1966 wheat season were well above average and it was one of the best seasons in the last decade. Both 1967 and 1968 were years in which very little rain fell during the wheatgrowing season. However, many operators who practised long summer fallowing grew good crops in 1968 on the moisture left in the soil after the heavy rain which fell throughout the shire in the summer of 1967–68. The average wheat yields per acre for the Boolooroo Shire for the four crop years 1965 to 1968 were 11·4, 33·5, 11·2 and 22·6 bushels respectively.

[3] It was not possible to obtain any other frame.

in the first year of the survey.[4] The number of growers in the sample was increased to 55 in the second year because four of the original sample who were not considered in 1966, as they did not grow wheat that year, did produce a crop in 1967. There was a strong tendency for operators in the sample to expand the area under wheat in the second year.[5] However, the low yields in 1967 more than compensated for the increase in area so that many growers in the sample produced less in 1967 than in 1966.

1 THE COST FUNCTION

Although the estimation of cost curves from cross-sectional data has many methodological problems [1, 3, 4, 7, 10, 13, 14 and 15], the point raised by Stigler deserves special comment [12, pp. 143–144]. Stigler demonstrates that if some costs are fixed in the short-run, and if output is subject to chance fluctuations, then cross-sectional data may indicate a fall in the average cost as output is enlarged, even if the firms are not in a situation where real economies of size exist. This problem is a version of the classical "regression fallacy", which as Walters points out, is not important if the results of the empirical analysis are to be viewed as expected cost functions and not as technological frontiers [14]. He adds that both for entrepreneurial decision making and for policy formulation, the expected cost function is the relevant curve [14, p. 211].

The majority of the results discussed later in this paper were obtained by fitting regression functions. These curves may be regarded as estimates of the expected relationship between production costs and levels of output. The technical frontier, or "true" long-run average cost curve, would be beneath the estimated curves. This follows because first, some of the operators in the sample are likely to be technically inefficient; secondly, many farms had excess capacity at least in the first year;[6] and

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[4] The rejection rate, which was 51 per cent, may appear excessive. However, the last wheat industry survey conducted by the Bureau of Agricultural Economics had a rejection rate of 30 per cent which was "much lower than that in either 1957 or 1962 surveys". [2, p. 8]. The Bureau gave "accounts too complex" as the reason for almost a quarter of all rejections in the latest wheat industry survey. In the survey of wheatgrowing properties in the Boolooroo Shire it was not necessary to reject any farms for this reason. Seventeen holdings were rejected because the operators did not grow wheat in 1966. Twenty-five holdings had to be omitted either because the operators were unavailable or because they were unwilling to co-operate. Another four were omitted because the wheatgrowing operation was exclusively conducted by sharefarmers. Seven holdings were excluded because they were operated by growers already in the sample.

[5] The same trend was evident throughout the Boolooroo Shire. In 1966 the area sown to wheat in the shire was 324,141 acres but this increased to 414,882 acres in the following year.

[6] A firm is said to be technically efficient when the plant used by the firm is being employed so that no reorganization or adjustments will allow the current level of output to be achieved with any less inputs. This implies that the firm is producing the chosen level of output with the given scale of plant, at least cost. The chosen level of output is said to be the capacity of the plant if, at that level of output, short-run marginal costs are equal to long-run marginal costs [12, p. 157].

thirdly, most farms experienced adverse random influences (due to weather and other factors) which inflated their costs.

Two other approaches which do not involve fitting an "average" regression were tried. The first involved the construction of free-hand envelope curves representing the "locus of lowest cost points" as suggested by Bressler [1, p. 529]. The basic assumption behind this technique is that at least some of the operators in the sample can be assumed to be efficient, producing at full capacity, and not subject to adverse random influences. The second additional procedure employed was the synthetic firm approach. The normative cost curves derived by this technique are not presented in this paper.[7]

1.1 THE DEFINITION AND ALLOCATION OF COSTS

A major hurdle in the estimation of costs of production for a farm product from farm survey data is the allocation of both cash and non-cash costs to the various enterprises when there is more than one enterprise on the farm. Every effort was made during the survey to separate wheat costs from other crop and livestock expenses on the basis of information supplied by the operator. Nevertheless, some arbitrary assumptions were still necessary.

The variable cash costs associated with the production of wheat on each of the farms were available either from the operator or his accountant and presented no serious problems.[8] Family labour was assigned an imputed cost based on the going rate for permanent employees. Despite the obvious theoretical objections, overhead costs were allocated so that the proportion charged against the wheat enterprise was the same as the proportion that gross wheat income represented of total gross farm income.[9] Straight-line depreciation was used with respect to wheat plant and equipment.[10] An estimate of the total capital employed in wheat

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[7] The paper, therefore, presents an entirely empirical or positive analysis of the survey data. For a discussion of the normative approach to cost/size relationships, see Madden [5, pp. 29–33]. For an Australian application of this normative methodology, see Ryan [8].

[8] The cost category "fuel and oil" presented some difficulty. In the first instance, the fuel and oil costs associated with the wheat enterprise were estimated on the basis of information provided by the operator. These estimates were later checked by calculating the expected fuel and oil charge, taking the area of wheat, the size of the tractor and the number of cultural operations into account.

[9] The most unsatisfactory aspect of the procedure adopted is that it has a disproportionate effect on the costs of small farms relative to the costs of larger farms. For example, the operator of a small holding growing 500 acres of wheat may earn 80 per cent of his gross income from wheat while his larger neighbour, who also grows 500 acres of wheat, only receives 40 per cent of his gross income from wheat. The method of allocating the overhead costs used in this study will, therefore, other things being equal, favour the larger landowner by assigning him a lower overhead cost per unit for wheat production.

[10] The annual rates of depreciation used were as follows: temporary wheat storage facilities, 20 per cent; tractors and harvesting machinery, 12·5 per cent; cultivating machinery, 10 per cent; sowing machinery, 8·5 per cent; and permanent grain storage facilities, 5 per cent.

production on each farm was obtained by using estimates of land values based on information supplied by the Reserve Bank of Australia, actual replacement costs for machinery, and book values for other improvements. Interest was charged at 6 per cent per annum.

1.2 THE MEASUREMENT OF OUTPUT

Theoretical cost curves are usually drawn showing the output of the product as the measure of the size of the producing unit. However, to measure the size of the wheat enterprise on farms in the Boolooroo Shire in terms of the number of bushels produced raises an obvious problem. Although twenty-eight operators in the sample harvested greater acreages in the second year, the poor season resulted in thirty-seven holdings being classified as having a smaller output of wheat in that second year. Climatic variation through its effect on yield will, therefore, not only represent a major source of variation in average total costs per bushel, but it will also introduce changes in the size of the operation, if this is measured by the number of bushels produced.

Another measure of size not subject to the vagaries of the weather to the same extent as production, is acres of wheat harvested.[11] If acres harvested is used as a proxy for output, it is necessary to decide whether the average total cost per bushel or the average total cost per acre should be used as the measure of cost per unit. Cost per acre takes only indirect account of any tendency for the yield to move up or down as the size of the operation expands. In fact, if there is a positive or negative trend in yield as a function of size, cost per acre is not strictly relevant to a discussion of economies of size. A simple regression analysis failed to reveal any significant change in yield as the acres harvested or the number of bushels produced increased.[12] Consequently both cost per bushel and cost per acre were considered when size was measured by the number of acres harvested.

1.3 THE MATHEMATICAL FORM OF THE COST FUNCTION

Choice of the appropriate mathematical model is very important to the analysis, because the form of the function will obviously determine the general properties of the estimated cost curve. Three functional forms which deserve consideration are the second degree polynomial, the rectangular hyperbola, and the power function. These three functions have the following general forms:

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[11] Yet another possible measure of size is acres sown. However, acres harvested has a more intuitive appeal as a proxy for output.

[12] The regressions were rerun with a dummy variable taking the value "1" for "advanced" operators and "0" for "ordinary" operators (see text for definitions). The regressions still did not suggest any trend in yield as the size of the operation was enlarged.

(1) $Y = a + bX + cX^2$
(2) $Y = a + bX^{-1}$
(3) $Y = aX^b$

where a, b and c represent parameters to be estimated, Y is the cost per unit, and X is the measure of size.[13]

2 RESULTS

In this study, costs have been classified either as "objective" or "other" costs (for a classification see appendix 1). In the view of many farm operators, their accountants and others, the costs of growing wheat consist only of the costs included in the objective category. Any surplus over and above these costs is regarded as a return to capital and management. It appears that in the Boolooroo Shire, a region recognized as being one of the low-cost, wheatgrowing areas in New South Wales, very few operators could grow wheat for less than an objective cost of 60 cents per bushel, even in a very good season such as 1966. On the other hand, the figures in appendix 1 suggest that the first advance of \$1.10 per bushel, paid by the Australian Wheat Board, was more than sufficient to cover not only the objective costs, but also the total costs of wheat production on the average farm in 1966, provided the area harvested exceeded about 500 acres.

The data in appendix 1 indicate that there is a distinct discontinuity in the long-run average cost curve. The cost per bushel fell as the area under wheat increased up to approximately 1,000 acres, that is, until one large set of cultivating and harvesting equipment was being used to its maximum technical capacity.[14] Beyond this size of operation, costs initially increased significantly and then gradually fell so that for wheat-growers harvesting about 2,500 acres, the average total cost per bushel was much the same as that for operators harvesting 1,000 acres.[15]

2.1 THE FITTED COST FUNCTIONS AND THE IMPACT OF SEASONAL VARIATION ON COSTS

All of the observations for the 1966 crop are presented in figs 1 and 2. The freehand curves showing the "locus of lowest cost points" in both diagrams probably represent close approximations to the "frontier" long-run average cost functions, at least as costs decline. The minimum points on these freehand curves may be interpreted as "local" minimum cost positions. As mentioned previously, the data in appendix 1 (and the results from the normative budgets) suggest that costs rise temporarily

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[13] The asymptotic regression model suggested by Stevens [11] was also considered but abandoned on the principle of Occam's Razor.

[14] The "maximum technical capacity" for a given plant is defined as the level of output at which the short-run average total cost curve for the plant reaches a minimum.

[15] The same conclusion can be drawn from the normative budget approach.

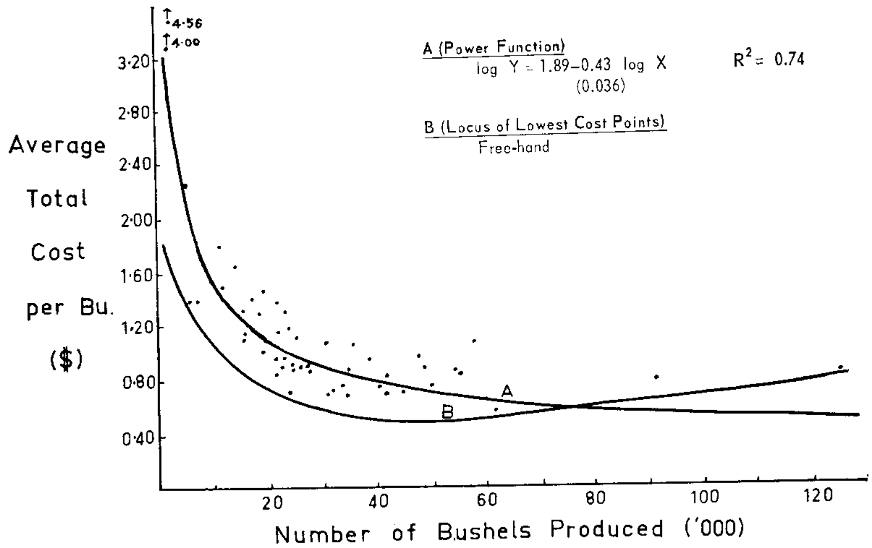

FIGURE 1: *Scatter Diagram and Various Cost Models with Output Measured by Number of Bushels Produced* (1966)

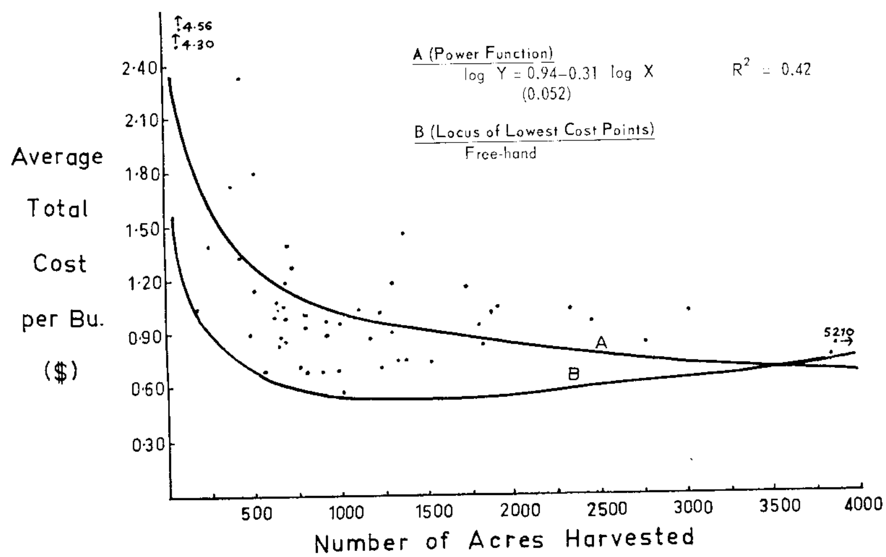

FIGURE 2: *Scatter Diagram and Various Cost Models with Output Measured by Number of Acres Harvested* (1966)

after the acreage exceeds 1,000 acres but then costs begin to fall again. The small number of observations from properties with more than 2,500 acres of wheat makes it impossible to estimate the level of output at which the "true" long-run average cost curves reach their "global" minimum.

All three statistical cost models fitted the data in fig. 1 better than they summarised the information in fig. 2. However, only the power functions have been plotted on the diagrams. The parabolas were not included because, although their functional form may be appealing on theoretical grounds, the survey data indicated an "L"-shaped rather than a "U"-shaped relationship. The rectangular hyperbolas were omitted because they gave very similar results to the power functions but did not fit the data as well in a statistical sense.

One would expect statistical models such as the hyperbola and the power function to fit the data better when output is measured in terms of the number of bushels produced, than when it is measured in terms of acres harvested. Consider two wheatgrowers who had a similar cost structure and who had sown the same area of wheat in the year in question. If one of these operators harvested a lower yield than the other due to unfavourable local climatic conditions, he would have had higher average costs per bushel. In diagrams such as fig. 1 the farm with the lower yield and the higher average cost will always be represented by a point above and to the left of the point representing the farm with the better yield. On the other hand, in diagrams where size is measured in terms of acreage (such as fig. 2) the farm with the low yield will be represented by a point vertically above the point for the other farm. This also explains why the impact of the inter-year seasonal variation is underestimated in fig. 3.

Figs 3 and 4 present the curves obtained by fitting a power function to the data for each of the years covered by the survey. Obviously the average cost of producing a bushel of wheat was higher in the year of poor crops (1967) than in the good season (1966). Fig. 3 suggests that when production dropped below 10,000 bushels, it could have cost as much as $1 a bushel more to grow the wheat in the poor year than in the good season. From fig. 4 the same conclusion emerges for operators who harvested less than about 700 acres. Fig. 3 indicates that as the size of the operation increased, the additional cost burden in the poor year dropped to around 20 cents. On the other hand, for the reason given in the preceding paragraph, fig. 4 produces a more realistic estimate indicating that large growers incurred about 50 cents per bushel higher costs in the year of poor yield.

2.2 THE IMPACT OF SEASONAL VARIATION AND NEW TECHNOLOGY

Wheatgrowers in the Boolooroo Shire were not all using the same production techniques during the survey period. With the assistance of university research workers stationed at Narrabri, the district agronomist in Moree, and a farm consultant in the area, a list of advanced farming

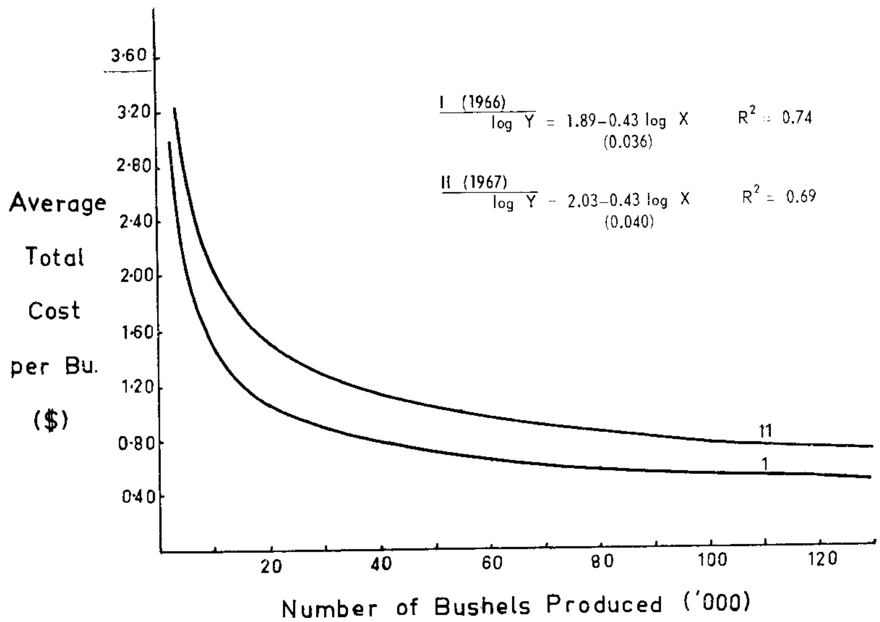

FIGURE 3: *Impact of Season Variation when Output is Measured by the Number of Bushels Produced*

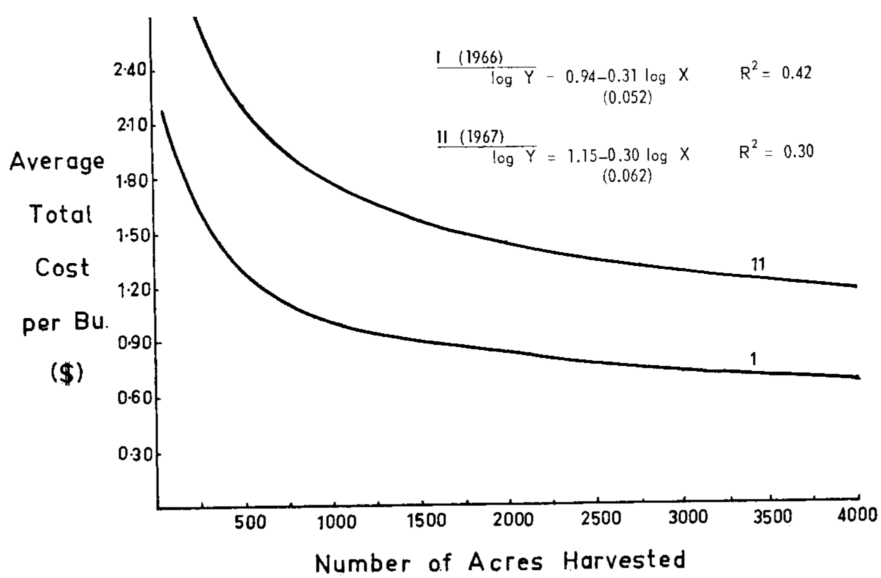

FIGURE 4: *Impact of Season Variation when Output is Measured by the Number of Acres Harvested*

procedures was prepared.[16] The operators in the sample were then classified into two groups, "advanced" and "ordinary", on the basis of whether or not they employed a majority of the advanced techniques.[17] Of the fifty-five operators in the sample, twenty-two were classified as "advanced" and the remainder as "ordinary". The advanced group consisted of both large and small wheatgrowers and there was no tendency for size and the adoption of new methods to be positively correlated.

Separate power functions were fitted to each group for both years. The four curves showing costs per bushel as a function of the number of bushels produced are presented in fig. 5 which, therefore, provides some indication of the impact of both seasonal variation and the adoption of new techniques on the cost functions. In both years on average the smaller operators in the advanced group had lower costs than the growers in the ordinary group. However, once the size of the enterprise exceeded 20,000 bushels the operators using the advanced techniques had higher costs than the farmers in the ordinary group in both years. The difference was most marked in the poor season (1967).[18]

As noted several times already, the climatic variation both between different farms in the same year and on the same farm between seasons, creates variations in yield which confuse the analysis. Although costs per acre may vary with yield, the relationship between average cost per acre and the number of acres harvested should be more stable than the functions discussed so far. Fig. 6 presents four power functions of this type and not unexpectedly, the statistical fits are good. In the good season on average the advanced technology increased costs by about $4 to $6 per acre, irrespective of the size of the operation. In the poor year the smaller operators in the advanced group were able to constrain their costs to much the same level as the costs of farmers not using the new techniques. However, as the size of the operation increased, the additional cost associated with the advanced practices did likewise.

These results imply a relatively complex interrelationship between the size of the enterprise, variations in seasonal conditions and the profitability of the advanced technology. Wheatgrowers, extension workers, and private consultants need to take an approach to decisions concerning such

[16] The list of advanced farming practices included the following: the use of fertilizers, the sowing of only recommended varieties, the adoption of recommended sowing rates and time of sowing, the use of advanced techniques for controlling weeds and pests, the use of long summer fallows and other cultural practices designed to achieve a better seed-bed, and the operation of a prime mover and implements which were matched with respect to their technical capacities.

[17] The two-way classification of the farmers, on the basis of a more or less subjective assessment of the level of the technology each farmer was using, would not necessarily produce the same division as grouping the operators on the basis of managerial ability as assessed by some other criterion. The subjective case-grouping approach to the analysis of cross-sectional data is discussed by Salter [9].

[18] The four corresponding curves showing costs per bushel as a function of acres harvested have not been presented. They do, however, indicate much the same picture as shown in fig. 5 except that the curves are further apart at the extremes and, as predicted above, do not fit the data as well in a statistical sense.

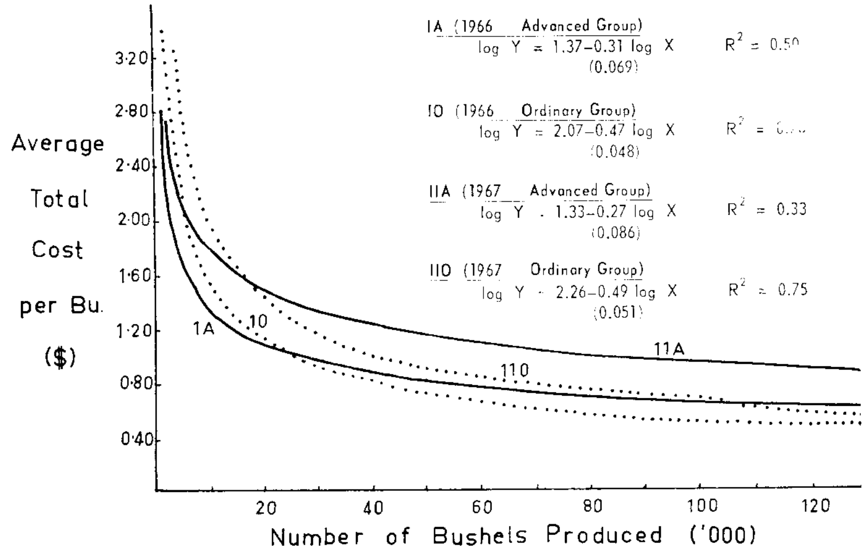

FIGURE 5: *Impact of Seasonal Variation and New Technology on Average Total Costs per Bushel as a Function of Bushels Produced*

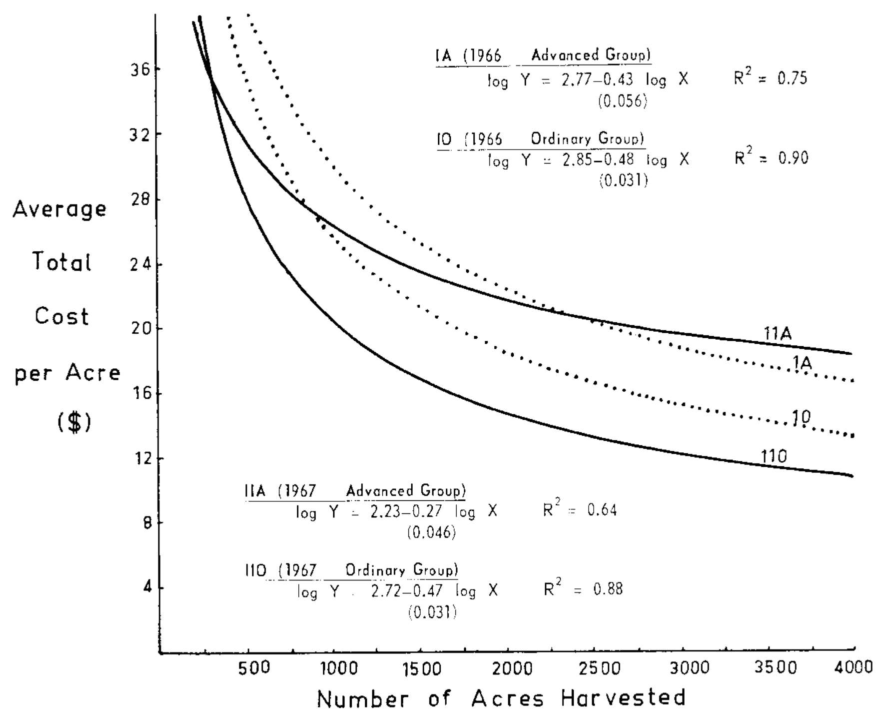

FIGURE 6: *Impact of Seasonal Variation and New Technology on Average Total Costs per Acre as a Function of Acres Harvested*

questions as the use of fertilizers which recognizes these relationships.[19] A practice which pays on one farm may be unprofitable on another farm with a larger wheat enterprise in the same year, or even on the same property the next season.

3 CONCLUDING COMMENTS

The analysis in this paper is concerned with the relationship between the cost of producing wheat and the size of the wheat enterprise on farms in an important wheatgrowing region of New South Wales. The study relates to two consecutive seasons of which the first was a year of good crops, while the second was a poor wheatgrowing season. The major conclusion to emerge is that in both years, there were substantial economies of size in wheat production, at least until the size of the wheat enterprise reached about 1,000 acres. However, there are four possible qualifications which deserve further comment.

Firstly, the apparent economies may be due to the larger wheatgrowing operations enjoying superior resource endowments, in particular, better soils, climate and management. The survey did not provide any evidence that the larger wheat enterprises were conducted on more fertile soils, in a better climate or by more competent management than the smaller operations. Secondly, the method of defining and allocating the overhead costs, especially the treatment of depreciation, may tend to exaggerate the decline in average costs as size is increased. Obviously, the calculation of depreciation by applying the same rates of depreciation (and the straight line method) to all farms has overlooked the possibility that some growers (especially the smaller operators who have excess capacity) may use their wheat machinery for many more seasons than other producers. Thirdly, it could be argued that the costs of the larger growers are biased downward unless the operator's wage allowance is increased as the size of the enterprise expands. In this study the operator's allowance is positively correlated with size, but only to the degree that the increase in the absolute size of the wheat enterprise is reflected in the contribution wheat sales make to total farm income. Fourthly, there is strong evidence of a discontinuity in the long-run cost function. The continuous functions presented in the diagrams do not reveal this important feature of the cost-size relationship.

While in a strict sense the results of this study apply only to the region studied and only to the 2 years for which data were collected, the analysis has broader implications. The recognition that there may be substantial economies of size in wheatgrowing is of considerable importance both for the management of wheat farms and for wheat industry policy. At the farm level, the results are of particular interest to wheatgrowers in the northwest of New South Wales. Provided minor adjustments are made to allow for cost inflation, the estimated cost functions provide a useful planning guide to the cost/size relationship in both good and poor

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[19] See Officer and Dillon [6].

seasons. In addition, the results highlight the need for caution in the adoption of new technology. In the policy context, the future of the wheat industry in Australia, given the present worsening trade prospects, will depend upon the industry being able to maintain its comparative advantage. Any policy measure, such as the present marketing quota scheme, which prevents wheatgrowers from taking advantage of the economies of size available to them, will increase the real cost of producing wheat in this country and hence erode Australia's comparative advantage in wheat production.

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APPENDIX 1

COST STRUCTURE FOR THE SAMPLE IN 1966

(Average Cost per Property in Dollars)

AREA OF WHEAT IN ACRES	1–250	251–500	501–750	751–1,000	1,001–1,250
No. of Farms	4	6	12	8	4
OBJECTIVE COSTS					
Variable					
Seed	134	571	742	1,294	1,076
Fertilizer	..	..	161	524	583
Fuel and oil	331	576	842	1,435	1,216
Wheat grading	34	136	179	313	236
Crop insurance	23	206	146	92	780
Contract services	561	1,182	861	1,014	1,079
Casual labour	76	118	518	707	338
Repairs to machinery	324	587	748	611	1,203
Pest control	..	17	26	6	96
Wheat dockage	66	94	163	..	7
Rail freight	1,094	3,714	5,013	7,714	7,453
Overhead					
Rent, rates and taxes	410	544	576	902	2,159
Telephone	108	160	99	128	148
Electricity	105	172	182	214	187
Accountancy and bank charges	100	112	131	160	198
Insurance	41	290	191	230	326
Permanent labour	950	1,825	1,929	2,075	2,418
Registration of vehicles	60	88	92	100	110
General administrative expenses	44	48	66	99	182
Depreciation of machinery	1,353	2,027	3,013	3,744	3,449
Depreciation of storage facilities	49	30	75	105	144
Total objective costs	5,863	12,497	15,753	21,467	23,388
OTHER COSTS					
Interest on capital invested	1,452	1,979	3,103	3,845	4,087
Operator's wage allowance	1,250	2,025	2,133	2,337	2,138
Total other costs	2,702	4,004	5,236	5,782	6,225
TOTAL COSTS	8,565	16,501	20,989	27,249	29,613
Average yield per acre (bushels)	29·7	32·1	32·3	33·6	27·5
Average total cost per acre	95·4	44·3	32·8	28·2	25·4
Average total cost per bushel	3·63	1·49	1·05	0·71	0·95
Average objective cost per bushel	1·86	1·08	0·81	0·54	0·68

APPENDIX 1—*continued*

COST STRUCTURE FOR THE SAMPLE IN 1966

(*Average Cost per Property in Dollars*)

AREA OF WHEAT IN ACRES*	1,251–1,500	1,501–1,750	1,751–2,000	2,251–2,500	2,501†
No. of farms . .	5	2	4	2	4
OBJECTIVE COSTS . .					
Variable					
Seed . .	1,505	1,730	2,284	1,863	3,807
Fertilizer . .	. .	1,070	1,200	2,232	2,345
Fuel and oil . .	1,643	1,570	1,726	2,078	3,645
Wheat grading . .	330	413	536	373	598
Crop insurance . .	594	587	. .	1,834	. .
Contract services . .	1,510	1,658	1,278	. .	3,918
Casual labour . .	347	1,385	788	516	1,935
Repairs to machinery . .	936	1,216	920	2,670	2,881
Pest control . .	323	. .	675	73	47
Wheat dockage . .	1,141	. .	. .	. .	. .
Rail freight . .	7,576	6,119	8,318	8,453	12,527
Overhead					
Rent, rates and taxes . .	1,438	1,704	1,076	1,347	4,554
Telephone . .	179	120	118	239	569
Electricity . .	208	252	326	226	704
Accountancy and bank charges . .	143	145	169	529	673
Insurance . .	518	474	204	325	904
Permanent labour . .	1,783	2,338	2,420	3,432	2,690
Registration of vehicles . .	111	55	142	215	244
General administrative expenses . .	130	76	162	333	163
Depreciation of machinery	3,508	3,500	4,054	5,089	8,256
Depreciation of storage facilities . .	93	235	162	285	195
Total objective costs . .	24,016	24,647	26,558	32,112	50,655
OTHER COSTS					
Interest on capital invested	5,329	4,974	7,409	9,210	12,746
Operator's wage allowance	2,382	2,100	2,573	2,625	2,378
Total other costs . .	7,711	7,074	9,982	11,835	15,124
TOTAL COSTS . .	31,727	31,721	36,540	43,947	65,779
Average yield per acre (bushels) . .	27·0	16·9	22·6	18·9	21·6
Average total cost per acre	25·2	18·3	20·1	19·3	16·8
Average total cost per bushel . .	1·01	1·08	1·04	1·02	0·77
Average objective cost per bushel . .	0·64	0·84	0·73	0·74	0·56

* The class 2,001 to 2,250 acres has been omitted because there were no sample farms in this range.

† Actual Acreages: 2,750, 3,000, 3,800, 5,200.