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Economies of Size on Irrigated Cotton Farms of the Texas High Plains

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SUMMARY

The study analyzed the economies of size available to irrigated cotton farms in the Texas High Plains. The findings show that the one-man farm with adequate capital can be as efficient as any larger size of farm. In fact, a 440-acre farm (102 acres of cotton) operated by one man with a set of six-row machinery can achieve an average cost of less than 71 cents per dollar of gross income. The larger farm sizes analyzed in this study extended to the five-man farm operating more than 1,700 acres of farmland, including some 550 acres of cotton. None of the larger sizes are capable of achieving lower average costs than the one-man farm.

The synthetic firm approach was used in this analysis. Farms of various sizes were constructed, assuming advanced technology and prices projected to 1968. Several different crop and livestock enterprises and various cultural practices were included in the analysis. Gross income was used as the measure of output. Linear programming was used to determine the least-cost farm plan for each of several levels of output. Short-run average cost curves were calculated for different farm sizes, and the envelope curve was developed from these short-run curves.

Recent trends indicate that cotton farms in the Texas High Plains are extending their acreage beyond the least-cost point at 440 acres of farmland. In moving to larger sizes, farms do not achieve lower average costs or greater efficiency. But they do achieve greater profit. A one-man operation with six-row machinery can produce almost $60,000 gross income on a 440-acre farm. Net profit, or return to the operator's management, would be $17,400. This profit is over and above a return to the operator's labor ($2,569) and interest on his equity in the investment. By comparison, a five-man farm can earn more than $67,000, using 1,720 acres of farmland. Gross income on such a large farm would be $235,000. Thus, the five-man farm is at least $50,000 more profitable than the one-man farm. This possibility of greater profit is an attractive encouragement for a farm operator to expand the size of his farm business.

During the 1954-59 period, the number of farms in the Texas High Plains with more than 1,000 acres increased by only 5 percent, compared with a 10 percent increase in the number of farms with 500 to 1,000 acres. Farms with less than 500 acres actually decreased in numbers. Thus, the size range that is attractive and has been attained based on the changing size distribution of farms, is 500 to 1,000 acres. These sizes are attainable within the family type of business, where the management and most of the labor is supplied by the family rather than hired workers. The average sized farm family can supply most of the labor for an irrigated cotton farm with 1,040 acres of farmland, including some 331 acres of cotton. Investment required for this size of operation is $700,000 and the net return to the operator's management is more than $30,000.

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Economies of Size on Irrigated Cotton Farms of the Texas High Plains

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American agriculture is changing rapidly as a result of continuing shifts in demand and supply conditions and changes in institutions affecting the farm sector. Demand changes as population and income increase and as consumer tastes and preferences change. Supply conditions change with the emergence of new technology, change in prices of competing products and as resource costs change. Changes in the institutions related to agriculture also have a marked effect. For instance, the farm price support program and credit policies modify the opportunities and uncertainties of farmers. As a result, agriculture is changing rapidly in several aspects.

The number and size distribution of farms is changing. Small commercial farms are dropping out in large numbers, yet in most areas and types of farming, agriculture continues to be composed mainly of family farms. Questions arise as to what will happen in the future under projected demand and supply conditions and proposed alternative farm programs.

One of the first questions to be answered in such an inquiry is the relation between size of management unit and the efficiency and profitability of production. This involves derivation of the envelope curve, or long-run average cost curve.

The primary objective of this study is to examine the efficiency and profitability of various sizes of cotton farms in the Texas High Plains. A secondary objective includes determination of the extent of potential economies achievable within the limits of a family farm business—that is, one in which the operating family provides the management, does most of the work, and is a financial risk-taker in the outcome of the operation.

Several studies of this type are being conducted in

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Figure 1. Hardland soils area of the Texas High Plains was the study area.

various parts of the country by the Economic Research Service, USDA, in cooperation with State Agricultural Experiment Stations. Each study involves an intensive examination of a specific type of farming in a selected area. In this study the irrigated cotton farm in the finer textured or "hardland" soils area of the Texas High Plains was examined. The area covers the major part of six counties in the Texas High Plains, Figure 1. These counties are Parmer, Castro, Swisher, Hale, Floyd and Crosby. Parts of Lamb, Briscoe, Lubbock and Dickens Counties are also included. Farm enterprises and production requirements are similar throughout the study area. The principal soil units to which this study applies include Pullman, Lofton and Olton clay loams and Amarillo, Berthoud, Portales, Mansker and Zita loams. These soil units are considered to be comparable from the standpoint of yield potentials and production requirements. However, there are soil units within the area of applicability that are not classified as hardlands that have different production potentials and require different production practices than the hardland soils. The main farm enterprises are cotton, grain sorghum, wheat, soybeans and stocker steers raised on wheat and other small-grain pastures.

Each of the counties in this study contains a high proportion of cropland, ranging in 1959 from 88 percent in Parmer County to 98 percent in Hale County. About 72 percent of the 2.4 million acres of cropland in the area was irrigated. The farm sample survey on which this study is based showed that in most cases farms are either completely irrigated or not irrigated at all. Nonirrigated farms occur in dryland areas where water is not available in sufficient quantities to support irrigation. These dryland sections were excluded from the present analysis.

The number of farms in the six main counties of the study area decreased from 5,932 in 1954 to 5,402 in 1959. The size distribution of farms in these 2 years is shown in Table 1. The proportion of farms with 200 to 499 acres of cropland increased from 45.5 to 47.0 percent during the 1954-59 period. The group of farms with 500 to 999 acres of cropland increased even more—from 16.6 to 20 percent. Farms with less than 200 acres of cropland decreased from 34 to 29 percent of the total number of farms.

CONCEPTS AND PROCEDURES USED

Hypothetical firms were constructed as the basis of the cost analysis. Linear programming and budgeting were employed to determine the least-cost combination of enterprises for attaining selected levels of gross income. Advanced technology and projected prices were assumed. Details of the theoretical framework are published separately.[1]

Assumptions and Definitions

Several assumptions and definitions are essential to the study of economies of farm size and are discussed in this section.[2]

DATING OF COEFFICIENTS, PRICES AND PROGRAMS

The ultimate research question toward which this study is directed involves the average total cost of production that could be expected by cotton farms of various sizes over the next few years. In attempting to answer this question, it is necessary to conduct the analysis using resource and product prices, input-output coefficients and farm programs reflecting

[1]Bob Davis and J. Patrick Madden, "Theory and Procedures for Studying Economies of Size on Irrigated Cotton Farms of the Texas High Plains." Texas Agri. Expt. Sta. MP 780.

[2]These concepts are discussed in greater detail in "A Study Guide for a Cooperative Project in Economies of Size, Part 1." FPED, ERS, USDA, Washington, D. C., November 1, 1963.

TABLE 1. SIZE DISTRIBUTION OF FARMS IN THE SIX MAIN COUNTIES OF THE HARDLANDS AREA OF THE TEXAS HIGH PLAINS[1]

Acres of Cropland	Farms				Change in number of farms, 1954 to 1959	
	Number		Percentage Distribution			
	1954	1959	1954	1959		
	Number	Number	Percent	Percent	Number	Percent
1-49	250	204	4.2	3.8	— 46	—18
50-99	365	271	6.0	5.0	— 94	—26
100-199	1430	1079	24.1	20.0	—351	—25
200-499	2692	2541	45.5	47.0	—151	— 6
500-999	981	1082	16.6	20.0	+101	+10
1,000-or more	214	225	3.6	4.2	+ 11	+ 5
TOTAL	5932	5402	100.0	100.0	—530	— 9

[1]Source: U. S. Census of Agriculture. Texas County Table 1, pp. 157-171, 1959.

conditions that are likely to exist in the future. Therefore, 1968 is used as a target date, and prices used were projected to 1968. Farm interviews revealed that all sizes of farms receive essentially the same prices for their products and pay essentially the same prices for their purchased inputs. Therefore, no quantity discounts and no price negotiation by larger farms were assumed in the present study.

Input-output coefficients were projected by using today's advanced technology under the assumption that over time most farmers will tend to adopt this advanced technonolgy. Such technology includes practices used by the more progressive operators in the study area, or new practices whose workability and economic feasibility has been tested either by farmers or agricultural experiment stations.

The analysis was conducted using constraints imposed by the farm programs that were in effect at the time of the analysis, namely the 1962-63 programs. The cotton acreage was limited to 35 percent of the cropland; grain sorghum base to 39 percent and wheat to 15 percent before diversion. Grain sorghum and wheat were diverted by the minimum allowable amounts, 20 percent and 10 percent of base acreage, respectively.

FARM PRACTICES CONSIDERED

The alternative farm practices involved in this study include variations in irrigation practice, machinery size and crop and livestock enterprises.[3]

Four alternative irrigation practices were considered. All four practices involve a single pre-planting irrigation, but they differ in the number of times the crop is irrigated after it is planted. Thus, one of the alternative practices involves only a pre-planting irrigation and no post-planting irrigation. Other practices involve a pre-planting plus one post-planting irrigation, a pre-planting plus two post-planting irrigations, and a pre-planting plus three post-planting irrigations.

Two alternative sizes of tractor and machinery, four-row and six-row, were considered in this study. The specifications of these tractors and their complements of machinery are given elsewhere.[4]

The main crop enterprises considered in this study were cotton, wheat, grain sorghum and soybeans. Alternative practices included each of these crops produced with different combinations of tractor size and number of irrigations.

Several beef production enterprises also were considered. These enterprises differed with respect to the buying and selling weights of the steers, the rations used and the amount of grazing required.

GROSS INCOME

Gross income is defined as total revenue from the sale of farm products plus government price support subsidy payments.

TYPE OF FARM

Type of farm is based on the relative proportions of gross income coming from the various enterprises. A cotton farm is defined as one on which not less than 60 percent of gross income comes from the sale of cotton; the remaining 40 percent is made up by the other farm enterprises.

LAND AND IRRIGATION WELLS

Land was assumed to be available to the firm in unlimited contiguous quantities in increments of 40 acres. This farmland was considered to be 90.9 percent cropland and 9.1 percent waste, including ditches, roads, turn rows and playa lakes (low-lying areas usually submerged by winter rains). Each acre of cropland was assumed to provide 0.35 acre of cotton allotment, 0.39 acre of grain sorghum base and 0.15 acre of wheat allotment in accordance with the foregoing assumptions regarding supply control programs.

All cropland was assumed to be under irrigation. The irrigation wells produce 650 gallons of water per minute on a 16-day irrigation schedule. Under these conditions, one well could adequately irrigate 114 acres of land if operated 21.6 hours each day during the irrigation period. This is a typical size of irrigation well in the study area.

TENURE OF OPERATOR

This study is primarily concerned with a long-run planning situation. Thus, it assumes the operator is starting a new farm business for which he can gain control of the necessary production resources, and that he is interested in the specifications of alternative farm plans that will produce specified levels of total output at the lowest total cost.

The study in its present stage is not concerned with the problem of how operators obtain control over the use of resources, whether by ownership, renting or hiring. However, some form of control must be assumed for accounting purposes. Under competitive conditions, rent theoretically approaches ownership costs over a period of years.[5] Where this

[3]The budgets used in this study were modified from previous and concurrent studies. See Moore, Tefertiller, Hughes and Rogers, "Production Requirements, Costs and Expected Returns for Crop Enterprises — Hardland Soils — Texas High Plains," Texas Agri. Expt. Sta., MP-601, August 1962, and John R. Meharg's unpublished master's thesis, "The Influence of Alternative Price and Allotment Programs on Farm Organization and Income for Irrigated Fine Textured Soils on the High Plains of Texas." Department of Agricultural Economics, Texas A&M University, 1964.

[4]Davis and Madden, Ibid. Table 2.

[5]Heady, E. O., "Economics of Agricultural Production and Resource Use," Prentice Hall Inc., New York, 1952. Ch. 20 and 21.

relationship holds, the resources needed for any specified level of gross income are approximately the same irrespective of whether operators are owners or tenants. Therefore, for simplicity of calculations, this study assumes full ownership of all resources.

LABOR

Two classes of labor are recognized in this study — regular and seasonal. Regular labor is committed to the farm for the entire production season, irrespective of the extent to which it is actually used. The maximum number of man-hours available per man-year of regular labor is considered to be 2,500. No more than 300 hours per man are considered available in any 1 month. The total amount of regular labor available is the amount hired plus the amount supplied by the operator, allowing for the time he spends supervising and coordinating the farm business. Labor supplied by the operator's family is considered hired labor.

Seasonal labor is hired on a short-term basis (by the day, week or month) during peak labor loads. Bracero labor is considered to be available in whatever amounts are needed at 80 cents per hour.[6] The cost of this unskilled labor is included in the activity costs. The only seasonal labor hired in this study was for hoeing cotton.

PROFIT

In this study, profit is defined as the net return to the business after all resources are paid for at going market rates. Interest on investment is charged at 5 percent on "sunk" investment and 6 percent on operating capital (or annual capital) used to meet cash operating costs. Even the portion of the operator's time devoted to labor is accounted for at the going salary rate for regular hired laborers. All cash costs and depreciation charges also are deducted in calculating profit. The amount of this profit does not depend on the operator's equity in the farm business or the amount of labor supplied by his family. For an actual farm operator, this profit figure would be less than other common measures of net income, such as net cash income, net farm income and operator income.

Net cash income is gross income minus cash costs. This quantity indicates the cash remaining after paying all cash expenses for the year. Unless this figure is positive, the operator will be forced to draw on savings or outside sources of funds to continue in business, even in the short run.

Net farm income is net cash income minus depreciation. If this quantity is positive, the operator can stay in business indefinitely. He can replace his equipment, pay all cash costs and have cash left over. However, the remaining amount of cash may be so low that returns to the operator's labor, management and capital are below market rates. If this happens year after year, the operator will tend to find some way to earn a higher return for his resources, such as reorganizing the farm or changing his occupations. Net farm income as defined here is approximately equal to taxable income as defined by the Bureau of Internal Revenue.

Operator Income is net farm income minus interest on investment. This quantity represents what is left for the operator's labor and management after paying for all the other resources at market rates. If the operator has full equity in his land and equipment, as assumed in this study, the interest on investment is not a cash cost. Rather, it is an opportunity cost reflecting what the capital would earn if invested elsewhere at prevailing interest rates. If an actual operator owns less than 100 percent of his resources and therefore pays interest, both his net cash income and his net farm income will be lowered by the amount of the interest paid; but operator income will remain unchanged.

Profit or operator management income is defined here as operator income minus the opportunity cost for the operator's labor. This value is a return to the operator for his managerial role of running the business and bearing the responsibility for a profit or loss.

Analytical Procedures

Specific farm sizes were recognized in this analysis. Short-run economies were examined by increasing the utilization of a given plant to its full capacity. Long-run economies occur as farm size increases with all resources variable. This involves a comparison of the efficiency of various sizes of farms. A specific farm size is represented by a given level of the fixed resources, regular labor and machinery. Various degrees of utilization for a given farm size were represented by different levels of gross income. Thus, the plant size and level of gross income were specified in a cost-minimizing linear programming problem; then the least-cost combination of products and variable resources was computed for that specific plant and level of gross income. The cost-revenue ratio (total cost[7] divided by gross income) was later calculated to determine one point on the short-run cost curve for the specific plant size being considered. Additional points on the short-run cost curve were determined by setting the level of gross income at other levels representing different degrees of utilization of the plant and computing additional linear programming solutions. When a short-run average cost curve is plotted for this specific plant size, the

[6]The bracero labor program (Under Public Law 78) was terminated by an Act of Congress on December 31, 1964 after this analysis was completed.

[7]Total cost is calculated for each programming solution as the sum of the level of cost in the objective function plus the lump sum of costs pertaining to the plant size being examined.

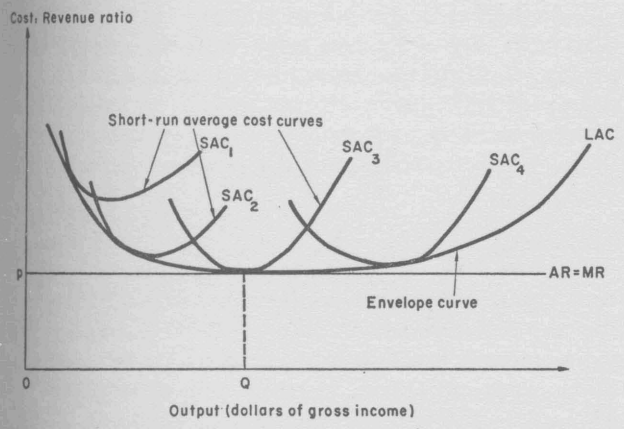

Figure 2. Theoretical illustration of short-run average cost curves and envelope curve or long-run average cost curve.

level of gross income is on the horizontal axis and the cost-revenue ratio is on the vertical axis as in Figure 2.

Shifting to the next short-run curve, the levels of the fixed resouces were set at new levels reflecting the set of resources that define the next farm size to be analyzed. Then successive linear programming solutions were computed for each of several levels of gross income, each reflecting a different degree of plant utilization. This process was repeated until a short-run average cost curve was determined for each farm size. Then the envelope curve was plotted as the tangency of the short-run curves.

EMPIRICAL RESULTS

The primary findings reported here deal with the efficiency and profit of different sizes of cotton farms producing various levels of output. Short-run average cost curves are presented to indicate how average cost changes as a given size of farm expands its output. The envelope curve drawn tangent to the short-run curves indicates how average cost varies between sizes of farms over a wide range of output levels.

Short-run Average Cost Curves

Short-run average cost curves were computed for 27 combinations of labor and machinery. It was found that six of these short-run curves lay below all the others. These six relevant curves contain the following sets of labor and machinery: one man and one four-row tractor, one man and one six-row tractor, two men and two six-row tractors, three men and three six-row tractors, four men and four six-row tractors, and five men and four six-row tractors. In each case, the tractor is accompanied by a complement of implements compatable with the size of the tractor. Figure 3 contains a graphic representation of each of the above short-run cost curves. A general description of the more important characteristics of each curve is presented in Table 2.

The least-cost farm plans derived in this analysis include only three enterprises: cotton, soybeans and grain sorghum. These enterprises occur with different levels of irrigation. Wheat and beef cattle enterprises do not enter any of the farm plans under the assumed 1968 projected prices.

The optimal farm plans primarily used the higher levels of irrigation. Virtually all the cotton is produced using three post-planting irrigations. Likewise, nearly all the soybeans that occur in the farm plans use the highest level of irrigation, which in this case is four post-planting irrigations. All grain sorghums use either three or two post-planting irrigations. Details of 64 optimal farm plans at various levels of output are given elsewhere.[8]

ONE-MAN FARMS

One-man farms are more efficient than larger farms up to an output of $75,000 annual gross sales, Figure 3. Four-row machinery provides the least-cost operation of farms up to the $33,000 output level (about 240 acres). Beyond this level of output, the six-row equipment is most efficient, Table 2.

[8]Davis and Madden. Ibid. Table 23.

TABLE 2. RANGE IN OUTPUT AND ACREAGE WITH LOWEST AVERAGE COST FOR EACH SIZE OF FARM

Size of farm			Range in output[1] and acreage with lowest[2] average cost for given farm size		Minimum points on ATC curves		
Number of regular laborers	Complements of equipment 4-row	6-row	Output[1]	Farmland acres[4]	Average cost, ratio[3]	Output[1] dollars	Farmland acres
			Thousands of dollars				
1	1		0- 33	0- 240	.732	43,600	320
1		1	33- 75	240- 680	.707	59,500	440
2		2	75-119	560- 920	.730	118,800	920
3		3	119-166	880-1,280	.709	152,700	1,120
4		4	166-200	1,200-1,520	.711	197,400	1,480
5		4	200-239	1,480-1,800	.712	234,600	1,720

[1]Output is measured as gross income.
[2]Lowest cost-revenue ratio for given levels of output, with land variable.
[3]Average cost is the cost-revenue ratio, total cost divided by gross income.
[4]The amounts of farmland are overlapping, as explained in the text.

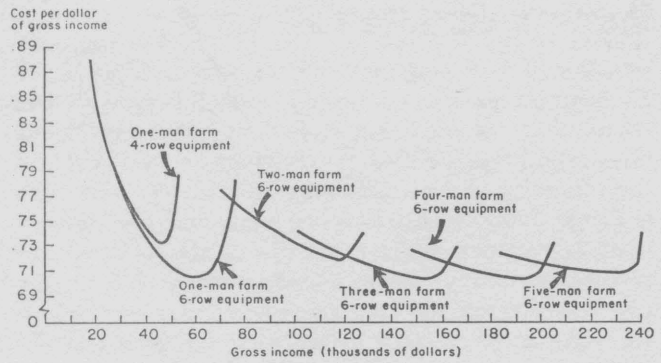

Figure 3. Short-run average cost curves obtained from irrigated cotton farms, Texas High Plains.

The short-run average cost curve representing the output levels attainable by a one-man farm using one set of four-row equipment has the shortest relevant output range and the steepest slope of the six curves presented in Figure 3. Average cost falls rapidly as output increases. This decline occurs primarily because the costs of "lumpy" factors such as machinery, buildings and labor are spread over a greater volume of output.

The lowest point on this curve occurs at an output of $43,600, Table 3. The organization of the farm at this point includes 320 acres of farmland, of which 102 acres is devoted to cotton, 50 acres to grain sorghum and 127 acres to soybeans. Investment required for this farm plan is $216,300.

This least-cost farm plan calls for the four-row tractor used at the unusually high rate of 1100 hours annually, despite an increased cost charged for the added wear and tear on the machinery. Also, the operator's labor supply for the critical months of July and August is used entirely at this level of production. Average cost at this point is $0.732 per dollar of gross income. The profit or return to operator management for such a farm plan would be $11,672 under the assumed prices. This is in addition to interest on the operator's equity in the investment and the $2,569 charged for the operator's labor.

As higher levels of output are produced with this farm size (one-man with four-row machinery), profits continue to increase up to an output of nearly $50,000 using 400 acres of farmland. This higher profit occurs even though average cost rises from $0.732 to $0.761 per dollar of gross sales.

Moving to a farm size with one man and six-row equipment, an entirely different cost structure emerges. As in the case of the four-row machinery, average cost drops sharply as output increases. However, the minimum average cost achieved using six-row machinery is much lower, reaching $0.707 cost per dollar of gross income at an output of $59,500 using 440 acres of farmland. As shown in Table 2, this $0.707 average cost is slightly below that achieved by any other size of farm considered in this analysis. Thus, all the economies of size available to irrigated cotton farms in the Texas High Plains can be achieved by a one-man farm with six-row machinery. The farm plan at this point includes 440 acres of farmland, with 140 acres of cotton, 121 acres of grain sorghum and 109 acres of soybeans. Investment is nearly $300,000. Net profit (management income) at this point is $17,400. As the output of this one-man farm is increased from $59,500 to $66,000 gross income, average cost rise; but profits continued to rise up to $18,300 with 520 acres of farmland.

An apparent peculiarity of Table 2 should be clarified. The cost-minimizing programming model used in this analysis determined the least-cost way to produce specified levels of gross income with a given supply of regular labor and a given amount and size of machinery. Land and other forms of capital were treated as variable resources. In calculating the least-cost organization for a given farm size (labor-machinery combination) to produce levels of output beyond where the regular labor supply is fully utilized, the farm organization shifts from labor intensive toward labor extensive enterprises. This causes the amount of land in the farm to increase rapidly as higher levels of output are considered. Moving to the next larger farm size, an additional regular laborer and set of machinery are added, and

TABLE 3. LEAST-COST FARM PLANS FOR SELECTED SIZES OF IRRIGATED COTTON FARMS IN THE TEXAS HIGH PLAINS

ITEM		Least-cost farm plans for farm size:					
Regular labor supply: Size of machinery:		One-man four-row	One-man six-row	Two-man six-row	Three-man six-row	Four-man six-row	Five-man six-row
Farmland	acres	320	440	920	1120	1480	1720
Investment	dollars	216,300	294,300	610,400	748,100	987,300	1,147,100
Cotton	acres	102	140	293	356	471	547
Grain sorghum	acres	50	121	261	306	408	470
Soybeans	acres	127	109	217	279	365	428
Gross income	dollars	43,600	59,500	118,800	152,700	197,400	234,600
Total cost[1]	dollars	32,000	42,100	86,700	108,200	140,300	167,100
Operator-management income[2]	dollars	11,600	17,400	32,100	44,500	57,100	67,500
Total cost-gross income ratio	ratio	.732	.707	.730	.709	.711	.712

[1]Total cost includes $2569 opportunity cost for the operator's labor, plus depreciation, interest on investment, and cash costs.
[2]Operator management income is a return to the business over and above the market value of all inputs, including the opportunity cost of the operator's labor.

it is no longer necessary to employ the labor extensive enterprises. In some cases, the amount of land required for least-cost production of a given level of output actually decreases when more labor becomes available. This causes the number of acres used by one farm size to overlap the amount used by a larger farm size, Table 2. For example, a one-man farm with one set of six-row machinery requires 640 acres to produce $72,800 of output, but a two-man farm with two sets of six-row machinery can produce this level of output on about 520 acres.

Six-row equipment gives rise to a lower average cost than four-row machinery primarily because of the differences in operating cost and performance rates. The six-row machinery will cover an acre during the time it takes four-row machinery to cover only 0.8 acre. But the hourly fuel, oil, lubrication and repair costs for the four-row machinery are 90 percent of those incurred by the six-row machinery. For this reason, four-row machinery has relatively higher operating costs for tillage operations. Thus, six-row equipment becomes more efficient than four-row equipment as soon as output becomes large enough to overcome the higher fixed cost of the six-row equipment.

In addition to these considerations of operating cost and performance rates, the six-row machinery has the added feature of requiring less of the farm operator's time per acre for each tillage operation. This increase in labor-use efficiency enables the operator to employ more of the labor intensive enterprises, such as cotton, which result in a lower total cost per dollar of gross income.

It is not surprising, therefore, that the one-man farm using four-row machinery would have a lower average total cost for the smaller levels of output, while the six-row machinery would have lower average total cost in the larger ranges of output. This is precisely what our analysis has shown.

FARM SIZES EMPLOYING HIRED REGULAR LABOR

There are costs, both fixed and variable, associated with using hired labor. These include the costs associated with items such as an extra tractor and machinery, a used pickup, housing for hired labor, the laborer's salary, a larger shop and barn and increased expenses for insurance, electricity and telephone. Some of these items also give rise to increased variable costs, such as the operating cost of the pickup and the machinery.[9]

The least-cost organization of all the farms using regular hired labor included only six-row, rather than four-row machinery. Details of the farm plan at the minimum point on the cost curves for two, three, four and five-man farms are shown in Table 3. Average cost for the two-man farm sinks only to about 73 cents per dollar of gross sales. Larger farms employing more regular laborers are able to achieve an average cost of about 71 cents, slightly above the cost attainable by the one-man farm with six-row machinery. Farmland involved in these least-cost farm plans ranges from 920 acres in the two-man farm to 1,720 in the five-man farm. Cotton acreage on these farms range from 294 to 547 acres. Grain sorghum and soybeans also enter these least-cost farm plans. Net returns attainable by these least-cost farm organizations range from $32,100 on the two-man farm to $67,500 on the five-man farm. In each size of farm, as output is extended beyond the least-cost point, total net returns increase even though average total cost rises.

The enterprise combinations and levels of irrigation fluctuate as output is increased while using a fixed supply of regular labor and machinery. These fluctuations occur primarily as additional resources become restrictive. The regular labor supply in July and August is one of the first restrictions encountered in all the farm sizes analyzed. The enterprises introduced at higher levels of output require less of the restrictive resource (for example, a cropping system that omits the July and August irrigations). In other cases, a variable resource such as land is substituted for the limiting fixed resource. A case in point occurs in the four-man farm. The July-August labor supply is fully employed when output reaches $185,800. As output is increased to $197,400, the farm organization is altered to include more land and consequently more cotton allotment. Then some July-August labor is shifted from the third post-planting irrigation of grain sorghum to allow an increase in the acreage of cotton, using three post-planting irrigations. As output increases, a greater percentage of the grain sorghum gets only two post-planting irrigations.

Envelope Curve

When the envelope curve is drawn smoothly tangent to the short-run average cost curves, as in Figure 4, it is decidedly L-shaped. The left-hand portion falls rapidly over a relatively short range

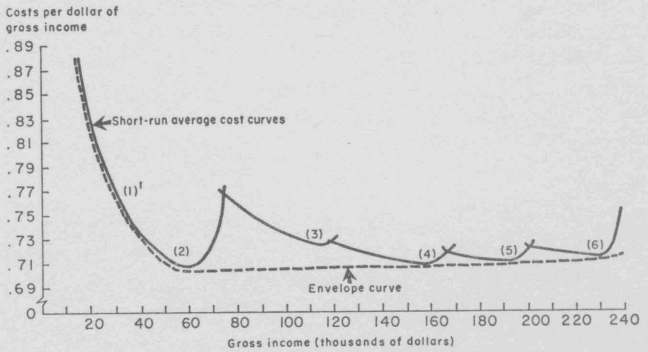

Figure 4. Long-run average cost curve for irrigated cotton farms, Texas High Plains, 1962.

[9]Davis and Madden. Ibid. Tables 7 to 11.

of output. The right-hand portion is nearly horizonal, rising very slowly over a wide range of output. Large farms employing two, three, four or even five-man-years of regular labor do not achieve lower average costs than this one-man farm. Thus, all of the technical economies of size available to irrigated cotton farms in the Texas High Plains are within the reach of the one-man operation, Table 4.

Profit

Profit is defined here as the return to the farm operator for the management function of making decisions, coordinating, supervising and bearing the responsibility for a profit or loss from the farm's operation. In calculating total cost, each resource is priced at market rates on an annual cost basis, including an opportunity cost for the operator's time available for labor.

Highest profits attainable with a given farm size generally do not occur at the least-cost level of production. Table 5 illustrates this fact for two farm sizes. On the one-man farm, as output is increased beyond the least-cost level of $59,500 gross income, average cost rises from $0.707 to $0.723 per dollar of gross income. Even so, profit rises by nearly $1,000. A similar rise in profit is seen in the four-man farm, where profit increases by more than $100, even though average cost increases from $0.711 to $0.715.

TABLE 5. COMPARISON OF OPTIMAL FARM PLANS WITH LOWEST AVERAGE COST AND HIGHEST TOTAL PROFIT FOR TWO SIZES OF FARM[1]

ITEM		One-man farm, six-row machinery		Four-man farm, six-row machinery	
		Lowest average cost	Highest profit	Lowest average cost	Highest profit
Farmland	acre	440	520	1,480	1,520
Cotton	acre	140	165	471	484
Grain sorghum	acre	121	148	408	420
Soybeans	acre	109	123	365	373
Gross income	dollars	59,481	65,922	197,412	200,691
Average total cost[2]	ratio	.707	.723	.711	.715
Profit[3]	dollars	17,396	18,263	57,109	57,259

[1]Size of farm as defined in this study is indicated by the number of regular laborers and the size of machinery used.
[2]Total cost per dollar of gross income.
[3]Return to operator management.

Total profit is presented graphically in Figure 5. The short-run average cost curves are included to facilitate comparison of average costs and total profits per farm. Total profit is indicated on the right vertical axis, while cost per dollar of output is presented on the left vertical axis. The total profit curve has an almost constant slope as it rises from its low point of $1,850 profit at $16,700 of output to more than $67,000 at an output level of $235,000.

When the two curves are considered simultaneously, several facts become evident. The envelope curve is relatively flat over a wide range from $60,000

TABLE 4. OPTIMAL ORGANIZATION OF FARMS AT SELECTED POINTS OF THE ENVELOPE CURVE

Item	Unit	Optimal farm organization					
Resources							
a. Regular labor (including operator)	man-years	1	1	2	3	4	5
b. Tractor and equipment, 4 row	No.	1					
c. Tractor and equipment, 6 row	No.		1	2	3	4	4
d. Farmland (90.9 percent cropland)	acres	320	440	920	1120	1480	1720
e. Irrigation wells	No.	3	4	8	10	13	15
f. Seasonal hired labor	man-years	0.2	0.4	0.7	0.9	1.2	1.4
g. Investment (average value)	dollars	216,285	294,347	610,114	748,087	987,256	1,147,086
Enterprise levels							
j. Cotton	acres	102	140	293	356	471	547
k. Grain sorghum	acres	50	121	261	306	408	470
l. Soybeans	acres	127	109	217	279	365	428
Costs							
p. Operator labor cost	dollars	2,569	2,569	2,183	1,541	642	0
q. Interest on investment	dollars	10,814	14,717	30,521	37,404	49,363	57,354
r. Interest on operating capital	dollars	249	336	636	876	1,089	1,347
s. Depreciation	dollars	3,481	4,449	8,862	11,370	14,771	17,307
Cash costs:							
Seasonal hired labor	dollars	519	714	1,493	1,817	2,401	2,791
Hired regular labor	dollars	0	0	2,569	5,138	7,707	10,276
Other cash costs	dollars	14,322	19,300	40,418	50,091	64,330	78,003
t. Total cash costs	dollars	14,841	20,014	44,480	57,046	74,438	91,070
u. Total cost	dollars	31,954	42,085	86,682	108,237	140,303	167,078
Income							
v. Gross income	dollars	43,626	59,481	118,781	152,684	197,412	234,647
w. Net cash income = v — t	dollars	28,785	39,467	74,301	95,638	122,974	143,577
x. Net farm income = w — s	dollars	25,304	35,018	65,439	84,268	108,203	126,270
y. Operator labor and mgt. income = x — q — r	dollars	14,241	19,965	34,282	45,988	57,751	67,569
z. Operator mgt. income = y — p	dollars	11,672	17,396	32,099	44,447	57,109	67,569
Ratios							
Total cost/gross income	ratio	0.732	0.707	0.730	0.709	0.711	0.712
Operator mgt. income per acre of land	$/acre	36.48	39.54	34.89	39.68	38.59	39.28

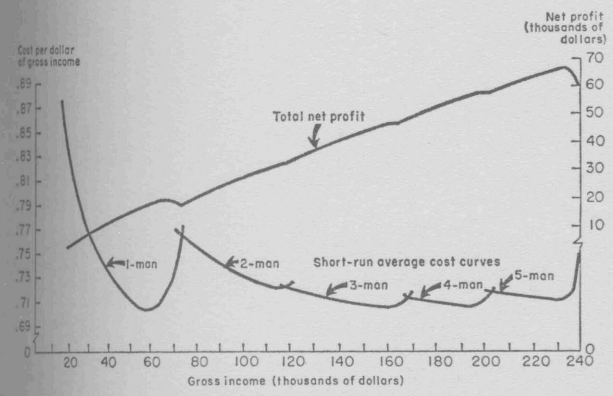

Figure 5. Entrepreneurial income per farm compared with the long-run average cost curve for irrigated cotton farms, Texas High Plains, 1962.

to $235,000 of output, indicating approximately constant average cost within this range. Meanwhile, the total profit curve has a rather constant upward slope along this range of output. The one-man farm with six-row machinery achieves the lowest average total cost, but the larger sizes earn higher profits. Thus, the incentive to expand farm production beyond $60,000 gross sales is higher profits, not greater efficiency.

Possibilities For Family Farms

The family farm is commonly defined as farm business in which the operating family provides most of the work and is to some degree an uncertainty bearer in the outcome of the farm business. In this study it was assumed that all labor provided for the farm other than that furnished by the operator himself was hired labor. However, the average sized American farm family provides 1.5 man-years of labor for the farm business. Thus, an average sized farm family can provide most of the labor for a farm that uses as much as 3 man-years of labor, including seasonal hired labor.

Seasonal labor is hired by cotton farms in the High Plains primarily for only one task, hoeing cotton. Thus, the amount of seasonal labor required per farm is directly related to the number of acres of cotton grown.

The one-man farm needs only 0.4 of a man-year of seasonal hired labor to produce $59,500 of output on 440 acres of farmland, including 140 acres of cotton. This farm achieves a lower average cost than any larger size of cotton farm in the Texas High Plains. Profit at this point totals more than $17,000. The two-man operation can handle 1,040 acres of farmland, including 331 acres of cotton, while employing less than 1 man-year of seasonal labor. Thus, even this two-man farm can qualify as a family farm. Investment required for this farm is nearly $700,000 and total net returns to operator management is more than $30,000. Clearly, the modern family farm is capable of achieving a highly efficient and profitable cotton operation in the Texas High Plains.

SUGGESTIONS FOR FURTHER RESEARCH

It is widely recognized that agriculture is undergoing rapid, continuous change. A clearer understanding of the growth and restructuring of farms is urgently needed by policy makers, legislators, farm leaders, businesses serving farms and farm operators themselves. The study reported here has provided some useful information on the potential efficiency and profit of different sizes of farm, assuming advanced technology and ignoring the problems of resource acquisition. However, many important questions remain unanswered.

1. What are the possible routes of resource accumulation through which a farmer may reasonably expect to shift from smaller to larger, from a less profitable to a more profitable size of farm business? For each of these alternative routes, several items need to be considered: (a) the extent to which financing is done by credit versus accumulated savings, (b) other resources needed, including such crucial factors as land, irrigation water and hired labor, (c) the expected pattern of year to year growth in size of business and net income and (d) the chances of success or failure.

2. How do the growth patterns of actual farm businesses compare with these feasible routes? What considerations deter farmers from pursuing each of these routes? How is the farm's growth pattern affected by such factors as the operator's equity, net returns, initial farm size, education and farming experience?

3. Finally, in attempting to better understand the changing structure of agriculture, these factors affecting the growth of individual firms must be placed in the broader context of the changes going on simultaneously in all farms in the local area and region, and in the nation as a whole. The overall quantities of land and farm labor available in a given area are limited, as are the markets for farm products. Changes in the number, size distribution and structural organization of farms occur as farmers compete for these limited resources, and as regions compete for a larger share of national and international markets.

Synthetic analysis of the potential efficiency and profit of various sized farms is a valuable first step in this broader spectrum of inquiry, but it falls far short of providing all the answers.

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