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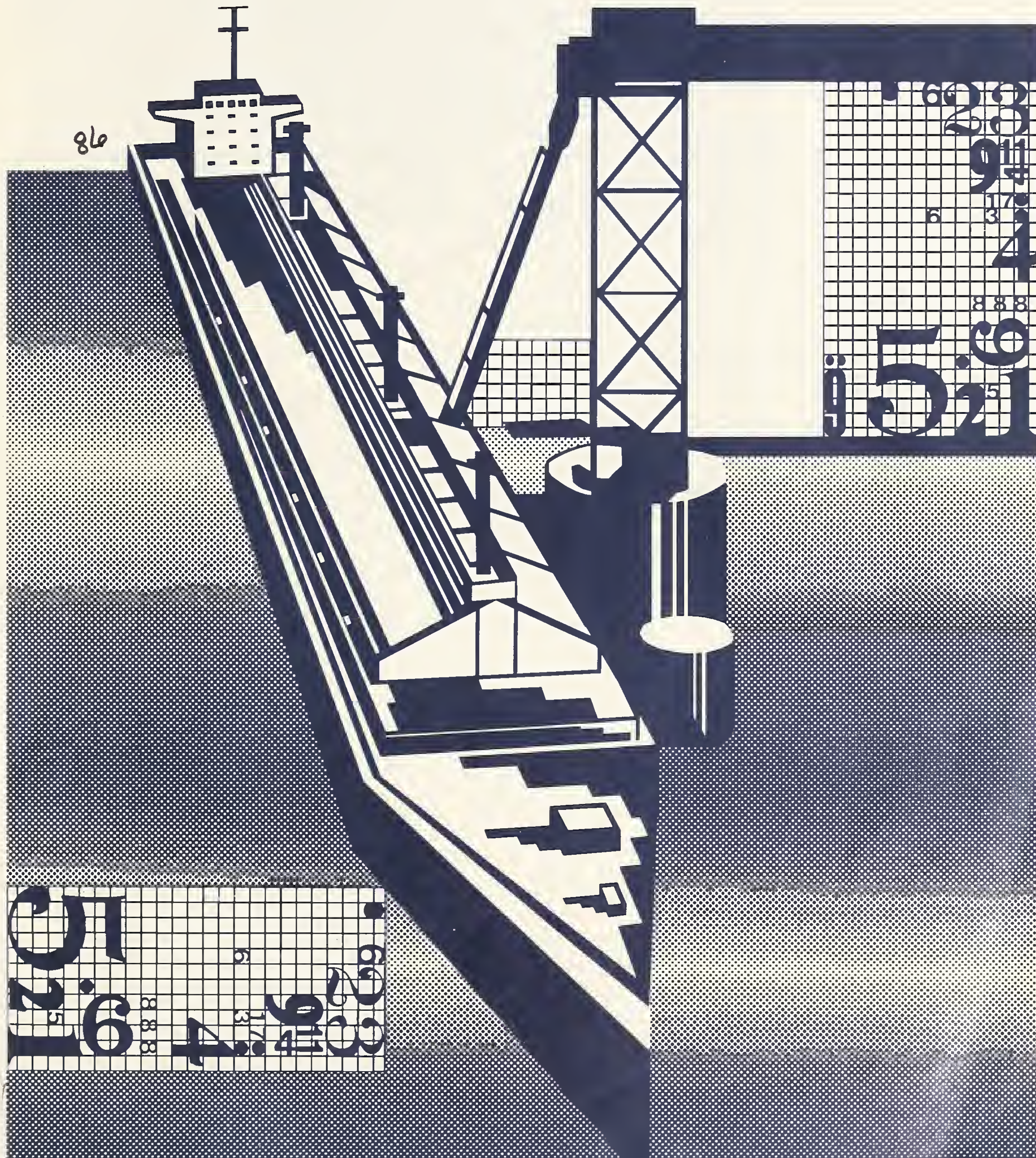
Grain Exporting Economies

Port Elevator Cost Simulations



Abstract

Grain Exporting Economies: Port Elevator Cost Simulations
ACS Research Report 56. Magid A. Dagher, University of Maryland. Bruce J. Reynolds, Agricultural Cooperative Service. Lynn W. Robbins, University of Kentucky

A major challenge for cooperatives involved in grain exporting has been to achieve adequate economies of size to be competitive while maintaining the flexibility to operate in a business that is also highly cyclical. Significant economies of size are often attributed to grain exporting, but until recently empirical estimation has been lacking. An economic-engineering technique is used to simulate cost curves for port elevators over a range of capacities. These results are used to construct longrun costs for identifying the economies and diseconomies of size. The simulation model is also applied to economies in the short run. An example is developed that uses simulation for managerial decisions when operating with excess port elevator capacity.

Key words: grain, economies, port elevator, exporting, economic-engineering, cost, simulation, cooperatives.

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Highlights

Economies of size and fluctuations in volume are chacteristics of grain exporting that result in periodic occurrences of low utilization of capacity. The former characteristic, coupled with the competitive nature of the business, has made it difficult for many cooperatives to achieve sustained involvement in exporting over long periods of time.

The existence of significant economies of size in grain exporting is a widely held belief. There are difficulties in articulating this belief as a hypothesis that can be empirically tested. A simulation model for port elevator costs provides a technique for estimating economies of size for an important component activity of the grain trade.

Based on engineering configurations and cost estimates for a range of capacities, the simulation resulted in the lowest cost facility having 4 million bushels of storage, 160,000 bushels per hour rate of receiving, and 240,000 bushels per hour of loadout capacity. The investment expense for this facility, model II, was $64.4 million based on 1983 costs. The data used in the simulation were appropriate for operating on the Mississippi River Gulf.

The estimated occurrence of diseconomies of size for facilities larger than model II was caused primarily by the receiving rate constraint, and the engineers' assumption that higher receiving capacity would be uneconomical. A sensitivity analysis showed that higher receiving capacity probably would not be uneconomical from the standpoint of capital costs. However, the engineers' assumptions were based on the tendency in most actual situations of building facilities to have higher load-out than receiving capacity.

The simulation model can also be applied to analyzing shortrun economies. The shortrun cost curves demonstrate the effect on per-bushel costs of changes in throughput per unit of time. When a change in export volume is expected to persist for a long period of time, port elevator managers have some, although relatively small, latitude in reducing their costs by adjusting variable and semivariable inputs. A comparison of shortrun cost curves for two labor shifts and for one shift working overtime was simulated. Reductions in per-bushel cost can be expected to be more significant for an older and relatively labor-intensive facility because it has a lower proportion of fixed to variable costs.

The existence of economies of size in port elevator operations and their effect on the per-bushel costs of exporting grain render small-scale participation extremely difficult if not infeasible over the long run. Simulations of port elevator operations also show the increase in per-bushel costs from significant decreases in export volume. These estimates, in conjunction with the evidence of business cycles in the export trade, have implications for strategic planning by grain cooperatives. Longrun participation in grain exporting by cooperatives requires financial preparation and investment for surviving periodic economic troughs.

GRAIN EXPORTING ECONOMIES

PORT ELEVATOR COST SIMULATIONS

Magid A. Dagher, Bruce J. Reynolds, and Lynn W. Robbins

It is possible for many industries to lower cost per unit of output by expanding capacity and corresponding volume of production. This reduction in average cost is defined as economies of size. Firms involved with the physical movement of grain often increase their capacity during periods when export volume is increasing and probably realize economies of size. When grain export volume abates, as it has recently, export capacity for realizing economies of size is underutilized and costs per unit of output rise. The competitive nature of the industry requires that firms achieve economies under normal or average market conditions and be able to maintain excess capacity during cyclical troughs in the export trade.

The existence of significant economies of size in grain exporting is a widely held but untested hypothesis (Caves, Conklin and Dahl, Jullierat and Farris, Thurston et al, Willis). An intuitive application of the survivor technique suggests the existence of substantial economies in grain exporting since the predominant share of the market has been controlled by the same large-scale firms over a long period. Econometric measurement using the survivor technique would require time series data that are not readily available from firms in the grain export industry.

Another method of measuring economies of size is the economic-engineering approach that entails simulating the cost functions of major activities or components of grain exporting. The estimation of the longrun cost curve of port elevators is an obvious candidate because of its critical role in the export process and its distinctive cost-throughput relationship. An economic-engineering simulation model has been developed for generating cost curves for port elevators and for dry bulk vessels used in ocean shipping of grain (Dagher).

Operation of port elevators is a distinctive characteristic of most grain exporting firms. Although some exporters either contract for or buy port elevator services and still others who buy f.o.b. port, those that exhibit persistent and large-scale involvement are firms that control port facilities. Grain cooperatives realized the importance of controlling port elevators when they began entering the export business during the 1960's (Reynolds). More recently Japanese firms have invested in U.S. port facilities to improve their capability to procure grains and oilseeds directly.

Grain firms that engage in exporting have several other component activities such as risk management, finance, and transportation that may display overall economies or diseconomies of size. All major functions and their coordination would have to be considered to estimate the economies of size for exporting grain by the method of cost simulation. Such an endeavor would require esoteric techniques of simulation or econometrics. However, simulated cost estimates of port elevator economies of size are adequate to test the hypothesis of grain exporting economies under the assumption that per-bushel costs for all other component activities do not rise with the expansion of capacity and grain volume. A few studies suggest this might be the case (Caves, Juillerat and Ferris, Thompson and Dahl). Furthermore, the presence of economies of size for a grain operation with multiple port elevators can also be estimated from simulation of one facility if the same assumption holds.

Many firms organize their port elevators and grain trading as a division of a multiple products and services business. Diversification of this kind can affect the economies of firm size (Baumol, Panzar and Willig). For example, per-bushel cost of exporting a given volume of grain might be lower for a diversified than for a specialized firm when the use or cost of certain inputs is shared over a diverse range of activities or larger revenue base. Port elevator cost simulations developed in this report contribute to estimating efficient grain operation size, but it is important to consider that diversification may also have an effect on cost and size.

An analysis of economies of size determines which facility has the lowest cost per unit of throughput. This optimum usually occurs when utilization is at or near full capacity. In other words, economies of size analysis does not concern the effect on unit cost of fluctuation in throughput. However, the technique of simulating cost curves provides a convenient method of estimating the response of per-unit cost to changes in throughput for a specific elevator size. Given a simulated shortrun cost curve, changes in per-unit cost due to annual increases (decreases) in export volume provide an estimate of economies (diseconomies) of capacity utilization. "Economies of size" is a longrun concept and "economies of utilization" is a shortrun concept.

Shortrun economies encompass more than just the behavior of cost from changes in a given facility's utilization. They also involve adjustments that managers make in response to significant volume fluctation. For example, exporters cannot directly and significantly affect foreign demand for or the domestic supply of grain, rendering throughput levels mostly beyond their control. Thus, when confronted with low utilization for a given capacity, the most that a manager can do to reduce cost in the short run is to exercise more control over variable inputs. For instance, labor is not strictly variable with throughput, but large changes in export volume may require adjustments that involve either layoffs or rehiring. Another example of shortrun capacity utilization management is the addition of overtime to a one-crew shift instead of adding a second shift. Adjustment opportunities are limited by the large share of fixed cost in a port elevator operation. Nevertheless, given persistent duration of low export volume, more fixed inputs can be made variable as the length of the run for decisionmaking is broadened. For example, more short-term leasing can be substituted for buying equipment, or more maintenance used to reduce the need for replacing physical capital.

The effect on per-bushel cost from adjusting inputs can be simulated. An example is developed in this report that concerns the decision to add crew shifts versus overtime to a one-shift operation. This example illustrates simulation applications. It may foster interest among managers to further develop this type of simulation, and they can identify the types of problems where simulation should be applied.

RESEARCH PROCEDURE

An economies of size analysis of port elevator operations focuses on the costs of storing and handling grain at U.S. port facilities.[1]* The economic engineering technique was used to design and make cost estimates on three representative model port elevators because historical data were not available for econometric analysis (French, French, et al.).

Models I, II, and III were designed with storage capacities of 2, 4, and 5 million bushels, respectively, and are representative of the small, medium, and large elevators of the industry. These model elevators were developed in the same manner that an architect or engineer would design a proposed plant and estimate its performance and costs.[2]

Costs for three additional model port elevators, labeled A, B, and C, were calculated by interpolating and extrapolating from data for models I, II, and III. They were assigned storage capacities of 1, 3, and 6 million bushels, respectively and represent some of the smallest, medium-sized, and largest port elevators. Investment and operating costs of models A, B, and C were estimated by fitting a quadratic function to the cost and volume data on models I, II, and III. A quadratic equation was fitted for subcost components or categories.[3] Subsequently, by substituting volume (elevator size, or grain volume) into the fitted quadratic equations, corresponding costs were obtained. Subcost components were aggregated to obtain total cost. The simulation of models A, B, and C provided additional shortrun average cost (SRAC) curves that contributed to construction of the longrun average cost (LRAC) curves.

Physical input requirements were determined by consulting port elevator engineers and operators and by observ-

*Footnotes are on page 13.

ing and analyzing port elevator operations of firms that participated in the research. Several operations were studied in the Gulf and Great Lakes port regions. Relevant input prices were collected from suppliers and other appropriate sources for constructing grain handling cost functions.

A FORTRAN program was developed to compute calculations involved in determining per bushel handling costs. The program incorporated fixed and variable cost equations for each model elevator. Variable cost equations were entered as a function of grain volume. The program was written to enable grain volume to be increased in equal increments up to the maximum throughput of the facility. After per-bushel handling costs were obtained, SRAC and LRAC curves were generated.

Model Port Elevators

Model port elevators I, II, and III incorporated the state-of-the-art technology available in 1983 and were representative of recently constructed and proposed elevators in the Gulf region. The rated maximum grain receiving rates of the model elevators were 90,000, 160,000, and 180,000 bushels per hour for models I, II, and III, respectively. The rated maximum load-out rates were 160,000, 240,000, and 320,000 bushels per hour for models I, II and III, respectively. The lower rates for receiving determine the limits to throughput.

Table 1 furnishes investment or initial costs of the model port elevators. These costs were estimated by F & P Engineers, Inc., for major components of the elevators, including engineering design, land, construction management, and contingency. These component estimates were then aggregated to obtain total investment costs.

Table 1—Investment costs for model port elevators, 1983[1]

Elevator components	Model		
	I	II	III
	Dollars		
Track, switches, site work	570,000	600,000	600,000
Rail receiving system	1,775,000	1,775,000	3,000,000
Storage system and associated equipment	14,003,000	21,373,000	24,825,000
Barge receiving system	11,240,000	14,700,000	15,600,000
Electrical	3,450,000	3,800,000	4,200,000
Dust control	2,725,000	2,600,000	2,900,000
Shipping system	5,250,000	7,250,000	8,200,000
Drying system	715,000	705,000	705,000
Construction total	39,728,000	52,803,000	60,030,000
Engineering and construction management (12)	4,767,360	6,333,360	7,203,600
Contingency (10)	3,972,800	5,280,300	6,003,000
Total cost	48,468,160	64,419,660	73,236,600

[1]The cost of land is reflected in the cost of elevator components.

Source: F & P Engineers, Inc.

Grain Throughput

The quantity of grain that a model port elevator can handle was assumed to be restricted only by the receiving rate of the equipment. Demand for its handling services was assumed to range from reasonably low levels to levels high enough to maintain the maximum throughput.

With respect to grain throughput for a typical operating year, it was assumed that two shifts' maximum grain throughput would be equivalent to 190 percent of one shift's maximum throughput. Also, three shifts' maximum grain throughput would be equal to 275 percent of one shift's maximum throughput. The less than linear increase in throughput reflects adjustments made for more downtime due to greater use. The elevators were assumed to have 349 operating days per year at full utilization of capacity.

Types of Costs

Costs are usually classified as fixed or variable for a shortrun economic analysis. An additional category, called semivariable, is made for costs that are neither completely fixed nor variable. This section discusses these categories and the economic engineering cost estimates.

Fixed Costs: This type of cost is unaffected by throughput. In this study, the following were classified as fixed costs: annualized investment or depreciation (which includes interest on investment), property tax, insurance on the port elevator, grain stock insurance, license and inspection fees, administrative expenses, transportation cost, plant supplies cost, and miscellaneous items. Table 2 gives annual fixed cost estimates for a one-shift operation. In the case of two- or three-shift operations, port elevator annualized investment is the only cost component that would change because the economic life of a port elevator is expected to decline as the number of shifts is increased.

The annual equivalent value approach (Smith, p. 100) was used to amortize port elevator investment:

$$AEC = K\left[\frac{i(1 + i)^n}{(1 + i)^n - 1}\right] - V\left[\frac{i}{(1 + i)^{n-1}}\right]$$

where

AEC = annual equivalent cost
K = initial cost of the facility
V = salvage value
i = interest rate, or rate of return
n = number of years of facility's economic life

The model elevators were assumed to have an economic life of 25, 20, and 15 years for one, two, and three shifts of operation, respectively. The standard equipment of these model elevators was also assumed to last the duration of the structure's economic life. A salvage value of 5 percent of the initial cost of the facility was assumed.

A before-tax rate of return of 11 percent was assumed. This rate of return is the opportunity cost of capital or the required rate of return. This rate is representative of export grain industry expectations in 1983.[4]

Table 2—Annual fixed operating costs, 1983

Fixed costs	Model I	Model II	Model III
	Dollars		
Annualized investment	5,732,087	7,618,591	8,661,327
Property tax	743,550	989,334	1,125,757
Property insurance	72,000	90,000	108,000
Grain stock insurance	26,400	52,800	66,000
License and inspection fees	1,221	1,232	1,440
Administrative expenses	175,675	193,195	210,715
Transportation	9,549	9,549	9,549
Plant supplies	2,500	3,000	3,100
Miscellaneous	96,000	114,100	120,141
Total fixed costs	6,858,982	9,071,801	10,306,029

Sources: F & P Engineers, Inc.; USDA-AMS; Alexander and Alexander of Texas; Producers Grain Corporation, and other grain companies.

Port elevator taxation was based on 15 percent of the market value of the facility. The assessed value was taxed at the rate of 102.57 mills, or \$102.57 per \$1,000. Port elevator insurance, on the other hand, provides coverage on all real and personal property and was estimated by Alexander and Alexander of Texas. The firm also provided guidance on the determination of grain stock insurance, which is purchased on a loss limit basis. This study assumed coverage on grain volume equivalent to port elevator capacity.

A Federal or State license is required to operate a port elevator, and this expense is applied to the model port elevators. Other fees include a one-time inspection fee, an average annual user fee, and an employee license fee issued to workers designated to inspect, grade, or weigh grain (USDA-AMS, pp. 16-17).

Administrative expenses are incurred for supervising elevator operations and for covering costs of management, secretarial help, and bookkeeping services. Additional expenses include rent, utilities, telephone, postage, travel, dues, subscriptions, donations, and auditing. The cost of transportation includes the annualized cost of vehicles and vehicular maintenance and repairs, which are used for in-plant and external plant transportation.

Cost of plant supplies typically includes expenses on lubricants for machinery and equipment, tools, pesticides, fire extinguishers, and sacks. Miscellaneous fixed costs are the fixed component of some of the semivariable cost items — for example, electric power and maintenance and repairs.

Variable and Semivariable Costs: Port elevator variable costs are those that vary with grain volume handled, and semivariable costs are those that change with additional shifts. In port elevator operations, few cost components are variable due to the capital-intensive nature of modern port elevators. This observation is supported by the fact that annualized investment is the major operating cost component. For this study, the variable and semivariable operating costs are the costs of labor, electric power, vehicular fuel consumption, maintenance and repairs, and the share these categories have of interest expense.

Table 3 presents labor cost requirements for superintendents, clerks, rail receiving operators, truck receiving operators, dockhands, electrical maintenance engineers, millwrights, and miscellaneous help.[5] Depending on the purpose of a simulation, labor cost should be either semivariable or variable. Semivariable conforms with the typical conditions under which workers are employed. In other words, they are paid regardless of brief periods of inactivity. However, several types of analyses require that labor and other inputs be simulated as variable cost. Therefore, two alternative simulation scenarios were developed.

Variable electric power cost is determined by obtaining the product of three components: (1) number of kilowatt hours (kwh) per million bushels of grain throughput, (2) number of million bushels of grain throughput, and (3) kilowatt hour cost of electricity. The electric power requirement on a per-million bushel basis decreases as elevator size increases because of increased flexibility in grain handling options.[6]

Fuel cost for intraplant and external plant transportation are incurred primarily for gasoline consumption. Typically, the amount of fuel consumed would vary with grain volume. However, because of the difficulty of determining the relationship between mileage driven and grain throughput, and also because fuel cost is relatively small, it is treated as a fixed cost for a one-, two-, or three-shift operation.

Maintenance and repairs consist of expected or planned elevator servicing, expected elevator repairs, unexpected elevator repairs due to random breakdowns, grounds maintenance, and rodent control service. This expense, like electric power, reduces as plant size increases on a million bushel of throughput basis.

Table 3—Selected variable and semivariable costs

Cost component	Model I	Model II	Model III
	Dollars		
Labor (1 shift)	426,000	536,900	536,900
Electric power (per million bushels)	532	456	428
Fuel:			
1 shift	2,938	2,938	2,938
2 shifts	3,375	3,375	3,375
3 shifts	3,813	3,813	3,813
Maintenance and repairs (per million bushels)	291	218	196

Interest on variable and semivariable operating capital is the economic cost of capital required to cover variable and semivariable costs during the course of a business year. The interest rate was assumed to be 11 percent.[7]

ECONOMIES OF SIZE

Simulation results for economies of size are presented for the three representative model port elevators (I, II, and III) and also for the computer-simulated model port elevators (A, B, and C). Results are presented in ascending order of elevator size— A, I, B, II, III, C, to facilitate the discussion on economies or diseconomies of size. Per-bushel costs of operating the model port elevators are calculated under two different scenarios.

Scenario 1

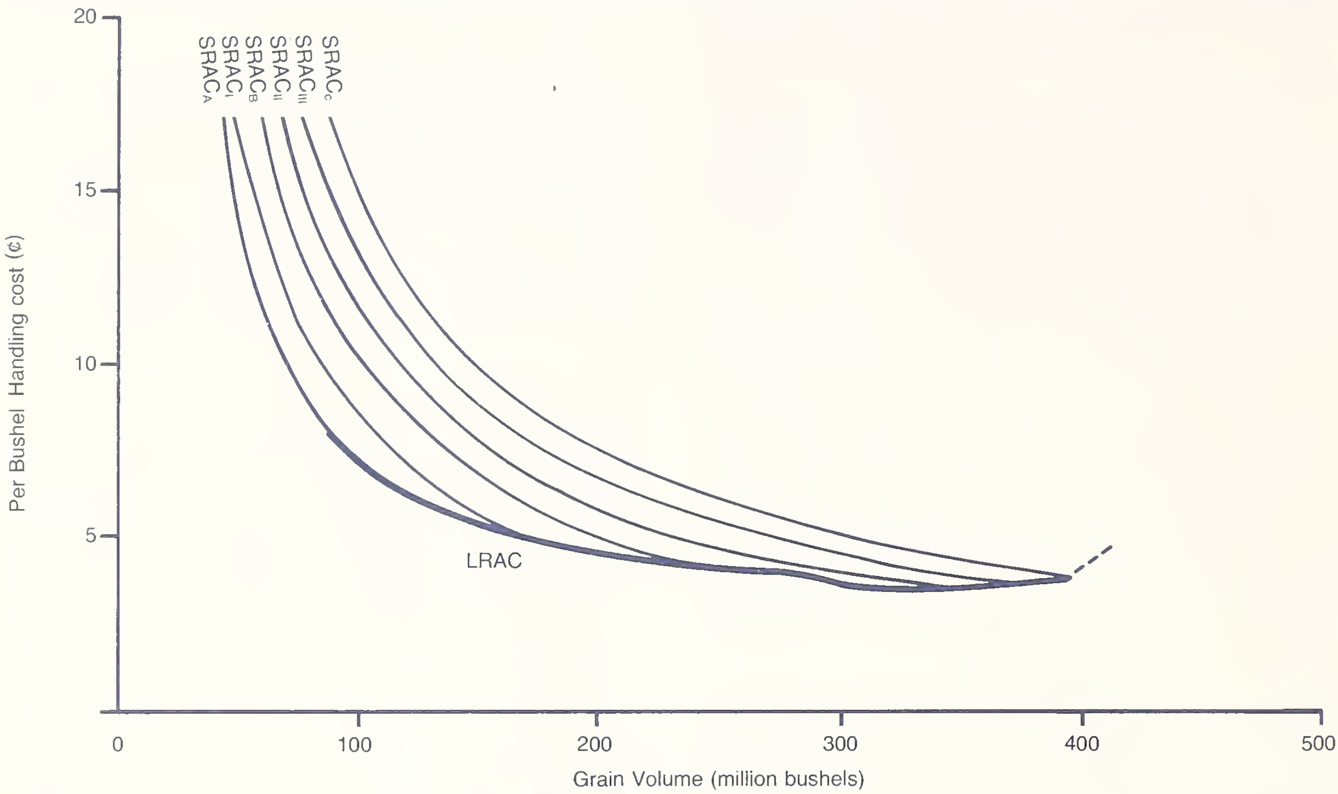
Scenario I treated labor as a semivariable cost. Operating costs were analyzed under one, two, and three 8-hour shifts. Table 4 gives per-bushel costs of handling grain at the model port elevators under the assumption of one shift of operation. Annual grain throughput ranged from a low level to the maximum capacity utilization level for each elevator, as specified by the consulting engineers. Per-bushel handling cost declined steadily over the range of throughput for all model elevators.

Figure 1 displays the SRAC curves and LRAC curve that were derived from table 4. These SRAC curves are all downward sloping, indicating that per-bushel handling cost declines as grain volume increases. These curves show that economies of utilization (i.e., economies emanating from high turnover rates of throughput) are substantial for all model elevators.

The LRAC curve traces the effects of elevator size or capacity on per bushel handling cost. Economies of size exist where the LRAC curve depicts decreasing per bushel cost throughout. Diseconomies of size are evident where the LRAC curve turns upward, making a U-shape. For a firm selecting a capacity to build, the SRAC curve with the lowest cost within its expected range of volume should be selected.

In economic theory, the term "envelope" is used to depict the LRAC curve because of its tangency to each SRAC curve at a single point. The facility with the lowest minimum SRAC determines the point of minimum LRAC. Simulation of throughputs higher than rated capacity would generate upward sloping or rising unit cost portions of the SRAC curves and thereby further verify that the estimate of minimum LRAC is correct. However, the end

Figure 1. Per-Bushel Cost of Handling Grain at Model Port Elevators, 1983. **(One Shift Operation scenario 1)**



points of the simulated SRAC curves were determined by the grain receiving rate restriction, which occurs in the downward sloping or declining unit cost range. The LRAC curve in this analysis is plotted from the lowest point on each SRAC curve. This method of constructing the planning curve is consistent with empirical studies on inland grain elevators (Mikes et al, Schnake and Stevens, Van Ausdle and Oldenstadt).

Of all the model grain elevators, model II achieved the least per bushel handling cost. All larger capacities exhibit diseconomies of size in port elevator operations as demonstrated by the upward turn of the LRAC curve. Reasons for diseconomies in the simulated elevators are: (1) the proportionately lower grain receiving rates for model elevators larger than model II, (2) the higher proportionate increase in investment cost for storage capacity beyond model II, and (3) the higher proportionate increase in electric power usage beyond model II. If there are feasible modifications in the facility configurations that would remove these constraints, different results would be generated. Such modifications can be introduced into the simulation model for estimating a different LRAC curve.

A similar cost analysis was executed for two-shift and three-shift operations. The results are not reported here but were similar to those obtained for a one-shift operation in that average costs fell consistently with increasing grain throughput and model II emerged as the lowest per bushel cost elevator. However, the results differed in magnitude. When operated at or near maximum throughput levels, per bushel costs of two- and three-shift operations are, respectively, about 1.5 and 2.0 cents lower than a one-shift operation.

Scenario 2

Scenario 2 involved relaxing the original set of assumptions by (1) allowing grain throughput level to dictate when to add a second or third shift, (2) treating labor as a variable input with respect to throughput by means of incrementally adding or subtracting work-hours, and (3) relating fuel use and cost directly and linearly to throughput. The modifications for scenario 2, while having the same findings of diseconomies of size as scenario 1, provide more accurate simulations for certain types of short-run managerial decision problems. For example, when

Table 4—Per-bushel cost of handling grain at model elevators with one shift: scenario 1, 1983

Annual volume handled (mil. bushels)	Model[1]					
	A	I	B	II	III	C
	Cents					
25.0	27.1					
50.0	13.6	16.1				
75.0	9.1	11.0	13.0			
83.3	8.2[2]	—	—			
100.0		8.3	9.8	11.3		
125.0		6.6	7.9	9.1	10.4	
150.0		5.5	6.6	7.6	8.7	9.8
175.0		4.8	5.6	6.5	7.4	8.4
187.5		4.5[2]	—	—	—	—
200.0			4.9	5.7	6.5	7.4
225.0			4.4	5.1	5.8	6.5
250.0				4.6	5.2	5.9
270.9			4.0[2]	—	—	—
275.0				4.2	4.8	5.4
300.0				3.8	4.4	4.9
325.0				3.6	4.0	4.6
333.4				3.46[2]	—	—
350.0					3.8	4.2
375.0					3.51[2]	4.0
395.9						3.75[2]

[1]Model size increases from left to right as follows: A = 1 million bushels, I = 2 million bushels, B = 3 million bushels, II = 4 million bushels, III = 5 million bushels, and C = 6 million bushels. Roman numerals identify the representative models and letters identify the computer-simulated models.

[2]These costs correspond with grain throughput levels that represent practical maximum volumes as specified by the consulting engineers and as restricted by receiving capacity.

Table 5—Per-bushel cost of handling grain at model port elevators with one shift: scenario 2, 1983

Annual volume handled (mil. bushels)	Model[1]					
	A	I	B	II	III	C
	Cents					
75.0	8.8	—	—	—	—	—
150.0	4.8	5.4	—	—	—	—
225.0	3.6	3.9	4.3	—	—	—
229.2	3.5[2]	—	—	—	—	—
300.0	—	3.0	3.4	3.8	—	—
375.0		2.6	2.8	3.2	3.5	—
450.0		2.2	2.5	2.7	3.0	3.4
515.7		2.0[2]	—	—	—	—
525.0			2.2	2.3	2.6	3.0
600.0			2.0	2.1	2.3	2.6
675.0			1.8	2.0	2.1	2.3
744.9			1.7[2]	—	—	—
750.0				1.8	2.1	2.1
825.0				1.7	1.9	2.1
900.0				1.6	1.8	1.9
916.8				1.55[2]	—	—
975.0					1.6	1.8
1,031.3					1.56[2]	—
1,050.0						1.7
1,088.6						1.65

[1]Model size increases from left to right as follows: A = 1 million bushels, I = 2 million bushels, B = 3 million bushels, II = 4 million bushels, III = 5 million bushels, and C = 6 million bushels. Roman numerals identify the representative models and letters identify the computer-simulated models.

[2]These costs correspond with grain throughput levels that represent practical maximum volumes as specified by the consulting engineers and as restricted by receiving capacity.

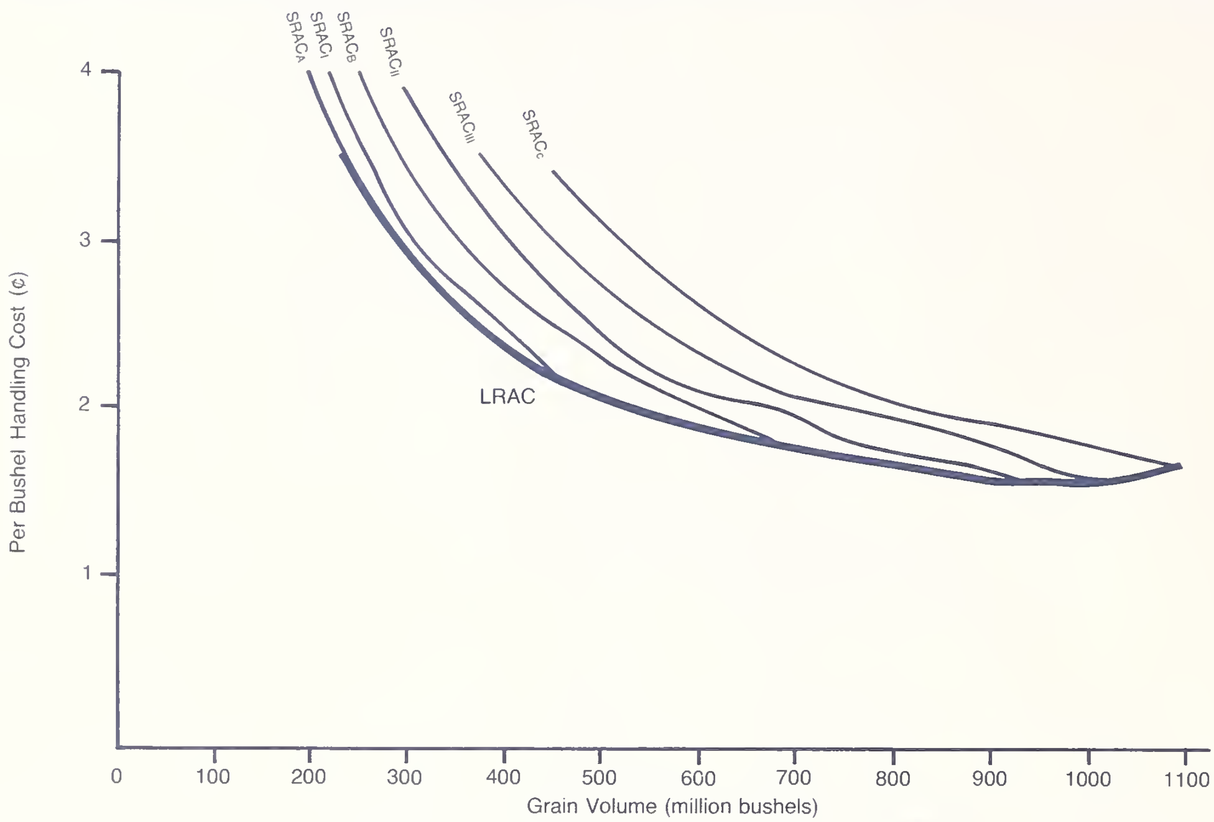
average gross margins fall below average cost, a facility must be able to determine that all variable costs can be covered in order to keep operating. Scenario 2 is also applicable when making decisions about adding crew shifts versus using overtime.

Table 5 presents the results obtained from the simulation that incorporated scenario 2's assumptions. These results are similar to those reported earlier, except for the magnitudes of per-bushel cost. Model II continues to be the most efficient port elevator. Figure 2 depicts the corresponding SRAC curves.

Sensitivity Analysis

As noted earlier, receiving rates are a concern because in the simulation they constrain throughput. Generally, load-out is higher than receiving capacity for the following reasons: (1) demurrage charges are high on ocean vessels while being lower for rail and nonexistent for barges on the receiving end, (2) time lags occur in waiting for vessels to arrive, to move in and out of the elevator berth, and to be cleaned, and (3) storage allows receiving to be lower than load-out rates without creating a bottleneck. However, the engineered receiving rate increased by

Figure 2. Per-Bushel Cost of Handling Grain at Model Port Elevators, 1983. (3-shift operation: scenario 2)



70,000 bushels per hour from model I to model II but increased by only 20,000 bushels per hour from model II to model III (recall that storage capacities for models I, II, and III are 2, 4, and 5 million bushels, respectively). Also, the cost for the 20,000-bushels-per-hour increase was proportionately larger than the cost for the greater increase in receiving rate from models I to II. Because of the critical role of the receiving rates in determining the capacity where diseconomies of size would occur, a sensitivity analysis was performed on the receiving rate variable.

Model III's receiving capability was increased over that of model II's by 35,000 bushels per hour. This receiving rate increase corresponds proportionately to the receiving rate increase between models I and II. A possible cost for constructing additional receiving capacity was varied until an amount was found that would result in constant returns to scale.

Once calculated, the constant-returns cost can be compared with engineers' estimates of the cost required to add 35,000 bushels per hour to receiving capacity. If the engineers' estimate is larger than the constant-returns cost, then longrun diseconomies exist beyond model II, the situation assumed by the engineers in the configuration that was simulated. Conversely, economies exist beyond model II if their estimate is smaller than the constant-returns cost.

The sensitivity analysis did not confirm the engineers' assumption that higher receiving capacity would have prohibitive cost. It showed that up to $2.94 million could be spent on the added 15,000-bushels-per-hour of receiving capacity before the cost would become prohibitive. This is about $800,000 more than the cost estimate used in the simulation to increase the receiving rate by 20,000 bushels per hour from models II to III (see table 1). In other words, by relaxing the receiving constraint, port elevator economies of size would be feasible up to and probably beyond the largest capacity that was simulated, model C.

The engineers developed their configurations from recently built or designed elevator projects, which are not easily adaptable to estimating the largest and hypothetical capacities for an economies of size analysis. Firms seek to establish facilities with a capacity to operate at lowest per-bushel cost within their expected range of volume, which is different from the optimal or minimum cost capacity because factors such as uncertainty about exports and competitor behavior affect decisions. While the simulated economies of size up to model II approximate point observations from actual operations, the results on diseconomies are tentative. Further research, with more proportionally scaled configurations, may determine economies of size for larger port elevators than are simulated in this report (Dagher and Robbins).

Summary of Economies of Size

Significant economies of size were estimated for port grain elevator operations. The lowest cost facility for a high-volume port region such as the Gulf was model II, which has 4 million bushels of storage capacity and a load-out rate of 240,000 bushels per hour. The much lower than proportional increases in the receiving rate for larger facilities caused diseconomies beyond model II. If this constraint on receiving should turn out to be nonbinding, then port elevator economies of size would extend beyond the 4-million-bushel port elevator to larger size facilities.

Although the simulated results for one activity are insufficient to empirically estimate diseconomies of size for an operating entity as a whole, port elevator operations probably represent a significant share of total costs. The cost of grain sold would be excluded from this share because it comes under the calculation of gross margins rather than costs of operation. Increases in port elevator capacity and throughput, that reduce per bushel handling cost, are unlikely to cause offsetting cost per bushel increases in other activities and services related to trading grain. It is more likely that coordination inefficiency of multiple facilities and of large-scale operations are a source of potential diseconomies of size for firms that specialize in grain trading or for a grain division of a firm.

SHORTRUN ECONOMIES

An economies of size analysis involves the longrun in which there are no constraints to changing the amount of any input. It estimates the change in per-bushel cost for a range of capacities as measured along an LRAC curve. By contrast, the existence of a constant physical capacity and associated fixed cost in the shortrun is what causes a reduction in per-bushel cost as measured along an SRAC curve for different rates of utilization. However, when rates of capacity utilization are low, it is often possible to reduce the increase in per-bushel cost by converting a larger amount of semivariable to a smaller amount of variable input and then increasing its intensity of use. In this case, shortrun economies involve more than moving along a cost curve to comprise the adjustments a firm makes in response to a change in its volume of grain exports.

Alternative shortrun adjustments can be simulated and compared with one another in terms of the SRAC curves they generate. In doing a cost analysis, the volume of throughput and gross margins are assumed to be determined externally and not under the control of port elevator management. These assumptions simplify the analysis and are to a large extent a realistic depiction of port elevator operations.

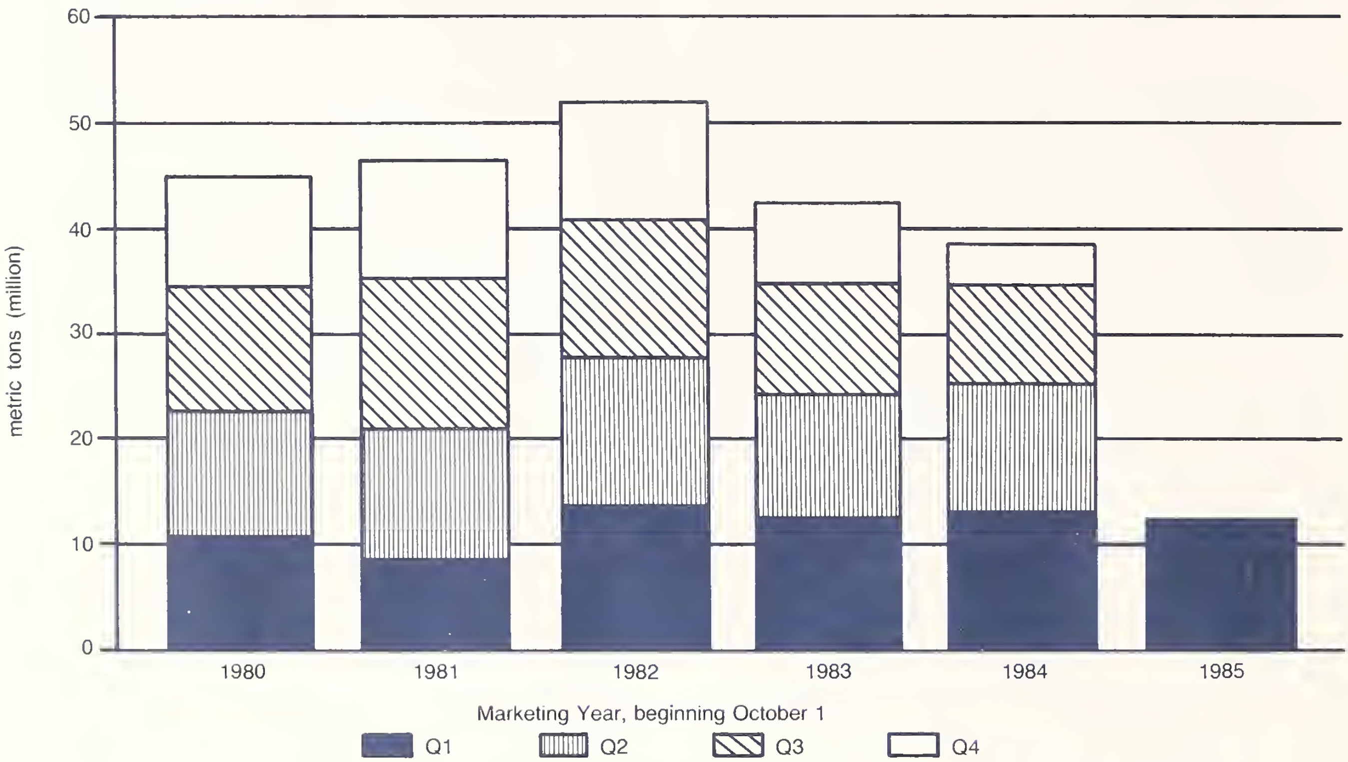
Changes in Volume

Before analyzing an example of shortrun adjustment, it is important to consider the size and time frame of significant changes in throughput. Without having actual grain volume data and capacities for individual port elevators, a general impression of throughput fluctuation is provided by USDA reports on inspections for exports (Grain and Livestock Market News). Quarterly volumes of U.S. exports of corn and soybeans from Mississippi Gulf ports and Hard Red Winter (HRW) wheat from the North Texas Gulf for the past 5 marketing years are shown in figures 3 and 4. Although data are available by month, quarterly periods, based on the corn marketing year (MY), are used because they are easier to observe in a graphical presentation and are a more significant time period for making input adjustment decisions.

Corn and soybeans are the predominant commodities for Mississippi Gulf elevators. Combined exports of corn and soybeans dropped by more than 9 million metric tons or 343 million bushels between MY 1982 and 1983 and by almost 2 million metric tons or 67 million bushels in MY 1984. Most of the decline occurred in the fourth quarters, dropping from 406 million metric tons in MY 1982:Q4 to 279 in 1983:Q4 and to 222 in 1984:Q4. Following these last quarter decreases, the first quarters of MY 1984 and 1985 returned close to the average volume of recent years (fig.3).

HRW wheat export volume was far below its average levels for the last quarter of MY 1984 and the first half of MY 1985. Changes in volume by quarter were also significant in MY 1980 and 1982, as graphed in 1,000-

Figure 3. Corn and Soybean Exports by Quarter Mississippi River Gulf Ports



metric-ton increments in figure 4. Although quarterly data facilitate comparisons over several years better than monthly data, the disadvantage is that they smooth out some of the changes that persist between the end of one quarter and the beginning of the next. For example, the comparatively low volume during the second quarter of MY 1982 continued for another month into the third quarter. Of course, these data are reported inspections and only approximate the actual timing of grain handling for shipment. The important point is that utilization of port facilities fluctuates significantly enough to affect costs.

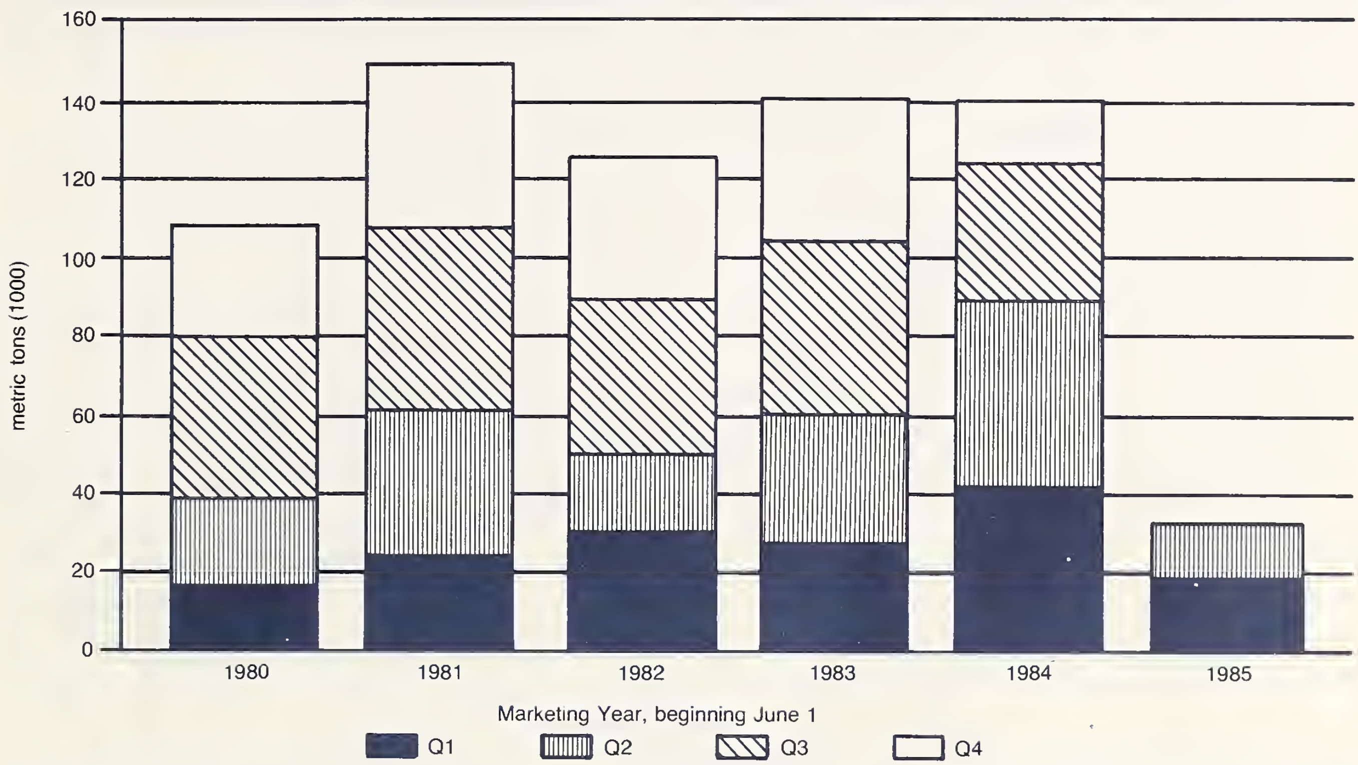
Simulating an Adjustment

In the analysis of economies of size, it was possible to compare several different elevator capacities with identical technology, cost structure, and operating relationships. This type of comparison is not possible among actual port elevators. Another advantage of simulation is in providing empirical results for unfamiliar situations and alternative responses that are anticipated. When a port elevator business experiences a large drop in its volume of exports, it will reduce its labor time and expense. The length of each shift could be shortened, or one or more shifts could be eliminated. Labor union contracts often limit the range of adjustment actions. But even in their absence, firms want to avoid layoffs because of the risk of losing experienced workers. In addition, the circumstance of fluctuation in throughput for port elevators requires that they maintain adequate flexibilty in their physical and human resources to handle peak demands. Such flexibility can be accomplished in some situations by the use of overtime (Lucas).[8]

An SRAC curve is plotted in figure 5 for an annual range of volume for one shift, working 8, 9, 10, and 11 hours per day. The wage rate after 8 hours is set at the usual time-and-a-half increase. On the same graph, the SRAC curve is plotted for a slightly larger range of volume for a two-shift operation. One hour per day of overtime does not commence until 350 million bushels (m.b.) is reached, and 500 m.b. is an estimated maximum for one shift.

The two SRAC curves begin to converge at higher rates of throughput per year because of the increase in labor

Figure 4. HRW Wheat Exports by Quarter North Texas Gulf



cost with each additional hour of overtime. One shift with overtime can handle any volume of throughput up to 500 m.b. at a lower per-bushel cost than a two-shift operation. One shift can put through a range of 200-300 m.b. per year at about one-half cent per bushel less than two shifts. Between 400-500 m.b., this cost difference narrows to about 0.2 cent per bushel, so if more than 350 m.b. were expected for the coming year, two shifts might be preferable because of flexibility requirements. If throughput were expected to be 350 m.b. or less, one shift with the opportunity for overtime would be able to handle a wide range of unexpected increases (fig. 5). These kinds of adjustments would be even more significant for an older and more labor-intensive facility than the one represented by model II in the simulation.

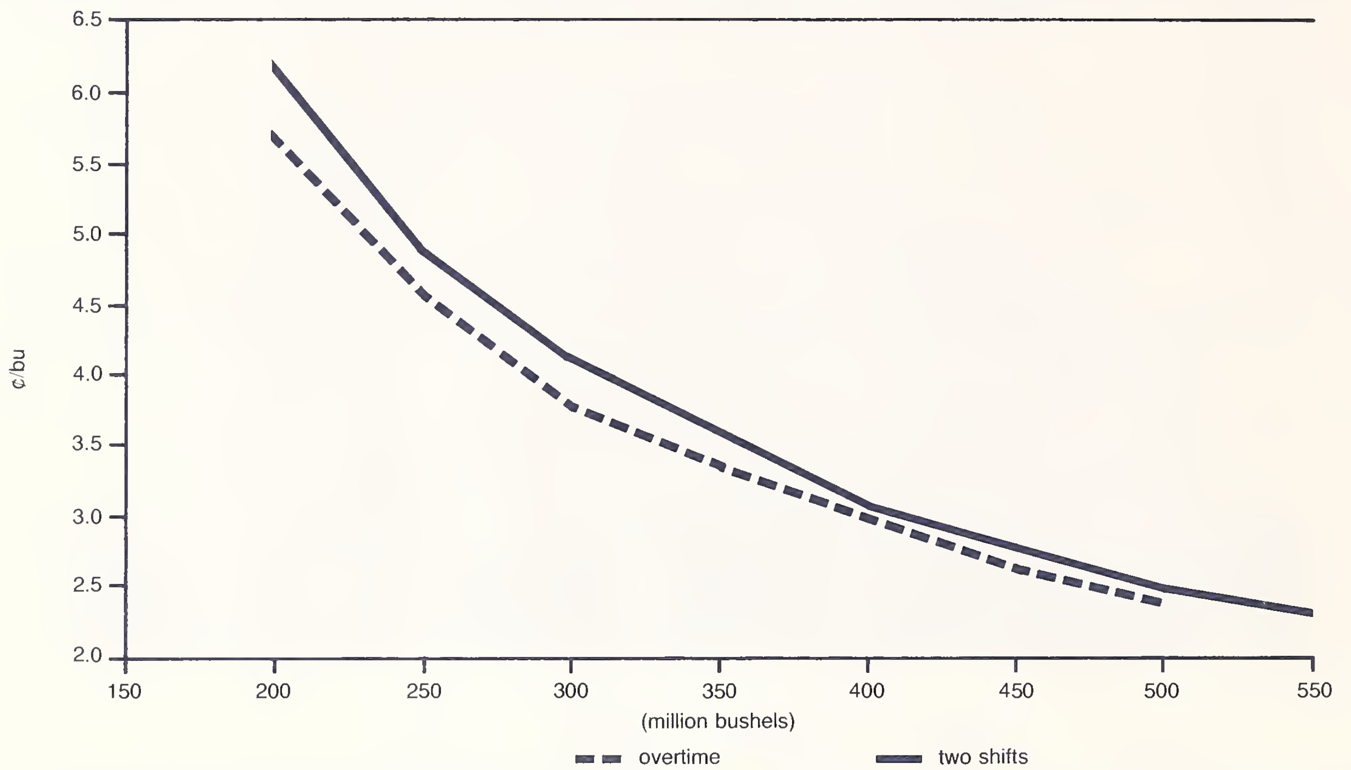
Labor union contracts, regulations, or worker availability may inhibit the use of overtime, but the ability to simulate such an alternative lets management know how much higher are the costs of operating under rigid employment schedules and how much could be paid for more flexibility. Although the calculations for comparing overtime with an additional shift are not difficult, far more complicated kinds of adjustments can be simulated.

CONCLUSION

The objectives of this research were to (1) gain a better understanding of economies of size in grain exporting, and (2) consider potential applications of simulated cost functions and curves to port elevator operations. In addition, there are implications of port elevator economies and export volume fluctuation for strategic planning.

The existence of substantial economies of size in grain exporting has often been inferred on the basis of intuitive and subjective evidence. Before the completion of the research that is the basis for this report, there had not been adequate empirical estimation of grain exporting costs for constructing functions and curves. Given the fact that firms are understandably reluctant to publicly release their operating data, simulation of port elevator costs provides the most accessible and effective approach to empirically estimating economies of size.

Figure 5. Model II Port Elevator Costs per Bushel **Comparing overtime with two shifts**



The estimation of port elevator economies of size up to model II provides verification for firm economies under the assumption that other costs on a per-bushel basis do not rise with throughput to an extent that offsets the port elevator reductions. The many other activities involved with exporting grain are probably also subject to significant economies of size. Further research on grain exporting economies can focus on these other activities and the coordination costs within large firms.

Variable inputs are often adjusted in an effort to lower per-bushel cost when grain exports fluctuate significantly. However, many potential adjustments are not made because managers require flexibility to be able to quickly raise throughput should exports increase. The extent to which simulation can be used in practice to analyze input adjustment alternatives requires experience with actual situations.

The simulations of port elevator economies of size and of utilization have implications about firm strategy, particularly in light of recent declines in exports. Firms appear to determine their port elevator capacities on the basis of economies of size considerations and their expectations of average throughput. When grain export volume abates, export capacity for realizing economies of size is underutilized and costs per unit of throughput rise. These circumstances indicate the importance of longrun survival strategies, such as diversification or investing past earnings for financing operations during a recessionary period. Diversification is a less preferred strategy for cooperatives than the latter. The withdrawal of several cooperatives from the control of port elevators suggests the importance of future research on strategies for preparing for cyclical troughs in the grain market.

Notes

1. Instead of numerous repetitions of the phrase "storing and handling" grain, the word "handling" will be substituted, because a port elevator is primarily a grain handling facility although some short-term storage may occur.

2. F & P Engineers, Inc., of Columbus, Ohio, a leading engineering consulting firm, designed the three model port elevators and made the construction cost estimates. This firm was formerly called R. S. Fling and Partners, Inc.

3. The quadratic functional form is $Y = aX^2 + bX + c$, where Y = cost, X = volume (elevator size, or grain volume), and a, b, and c are parameters. Because a set of three data pairs (cost, volume) are available for models I, II and III, the parameters a, b, and c can be obtained by the following expression for matrix inversion: $(X'X)^{-1}X'Y$.

4. Although the 11-percent rate of return is equivalent to the average prime lending rate for the 1983 calendar year, this rate of return reflects both the real rate and a discount premium for risk.

5. Salaries and wages do not include fringe benefits, because this information was not available at the time of the analysis.

6. The lower number of kilowatt hours per million bushels of grain throughput, as elevator size increases, can be explained in terms of the technical relationships that exist among elevator size, grain volume, and electrical power.

7. Same explanation as footnote 4.

8. Lucas develops some theoretical considerations that underlie this example.

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