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PROFIT COMPARISONS AND PRODUCT MIX IN THE AUTOMOBILE INDUSTRY

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ABSTRACT

This paper seeks to estimate the extent to which product mix contributes to the relative profit differences between Ford Motor Company and General Motors. To do so requires making several assumptions about the operations of the auto industry. These assumptions are detailed so that suggestions may be made to improve the analysis.

One of the main conclusions is that higher-priced cars have substantially higher profit rates than lower-priced cars. Because of GM's large market share in the higher-priced cars, GM has a substantial profit advantage over Ford. Other areas of profit differences that are investigated include vertical integration, pricing, options and option installation rates, interest income, tooling amortization, and overseas and nonautomotive operations.

BACKGROUND

This paper is being prepared as part of a research program on Evolving Competitive Aspects in Major Industries. Comments would be appreciated and should be addressed to the authors.

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PROFIT COMPARISONS AND PRODUCT MIX IN THE AUTOMOBILE INDUSTRY

Introduction

In a recent paper it was pointed out that it is difficult to analyze the differences in profit rates between automotive firms over a period of time because of variations in product mix.[1/] The present paper is an attempt to quantify some of the influences of product mix on profit rates in the automobile industry.

Another study contends that "a firm producing in the range of 400,000 cars a year would fully exhaust most of the production economies that exist."[2/] Since the production of each of the major manufacturers exceeds this amount, it would be helpful to see to what extent the profit differences may be explained by factors other than economies of scale, such as product mix. Product mix, as discussed here, simply means the proportion of a firm's output sold in various

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1/ Roger L. Wright, "Prices, Productive Efficiency, and Profits," Unpublished paper (Ann Arbor: Bureau of Business Research, University of Michigan, May 1971).

2/ Lawrence J. White, The Automobile Industry Since 1945 (Cambridge: Harvard University Press, 1971), p. 39.

price classes. It is known, for example, that the proportion of General Motors' sales is larger in higher-priced cars than Ford's. If there are no economies of scale differences between the two firms, how much of their profit difference can be explained by product mix?

Since this study is best viewed as exploratory, only the data for the 1969 model year are developed. Our approach attempts to compare the actual profits of Ford for that year to a level that might have been obtained if Ford had achieved the same product mix as General Motors. We outline our approach in great detail so that comments and suggestions can be made to improve the method of analysis.

In the first part of our study, we estimate the relative profit contribution of the major entities comprising General Motors and Ford. Thus, North American car and truck operations are separated from overseas and nonautomotive operations. We then found it necessary to develop estimates for a model year rather than the fiscal year used for financial reporting.

The major, or more heroic, assumptions are made in the second part of the paper, where we attempt to assign relative contributions to profits by major automobile lines; here we found it necessary to separate fixed cost components from variable costs.

Analysis shows that the relative magnitude of the sales mix factor is quite important in explaining the profit difference between Ford and General Motors. No attempt is made here to assess the implications of this finding, since the important point we are seeking

is whether or not the approach used seems to be reasonable. If the approach is valid then the analysis could be extended for other time periods and other companies.

I

FINANCIAL RESULTS

An examination of the profit performance of the Big Three in the auto industry from 1965 to 1970 reveals that, while the relative profit performance of each firm is significantly different, the relationship among the various companies has not changed materially and that General Motors (GM) holds a significant profit advantage.

In the 1965-70 period, GM's pretax return on sales averaged 14.1 per cent. In the same period Ford's average return on sales was 7.7 per cent, or 54 per cent of GM's level (55 per cent if we exclude the major strike years for GM and Ford), and Chrysler's return averaged 5.3 per cent, or 38 per cent of GM's level. These results are shown in Table 1.

GM also holds a significant lead in return on assets and return on equity. As shown in Table 1, GM's return on assets for the 1965-70 period was 23.8 per cent, compared with 12.3 per cent for Ford and 9.6 per cent for Chrysler. GM's pretax return on stockholders' equity for that same period was 32.8 per cent; Ford's return was 20.5 per cent, and Chrysler's return on equity was 17.8 per cent.

TABLE 1

Pretax Return on Sales, Assets, and Equity for Ford, GM, and Chrysler
(1965-70 Calendar Years)

	Return			Percentage of GM's Return	
	GM	Ford	Chrysler	Ford	Chrysler
On sales:					
1965	19.7%	11.4%	8.7%	58%	44%
1966	16.2	9.7	6.5	60	40
1967	15.0	1.3	6.0	9	40
1968	15.5	9.2	8.5	59	55
1969	14.2	7.6	2.7	54	19
1970	4.1	6.7	(0.5)	163	...
Average 1965-70	14.1%	7.7%	5.3%	54%	38%
On average assets:*					
1965	37.6%	18.8%	17.0%	50%	45%
1966	26.8	15.1	11.9	56	44
1967	23.0	1.7	10.4	7	45
1968	25.8	15.3	15.1	59	59
1969	24.0	12.3	4.1	51	17
1970	5.4	10.5	(0.7)	194	...
Average 1965-70	23.8%	12.3%	9.6%	52%	40%
On equity:					
1965	50.0%	29.4%	28.6%	59%	57%
1966	37.5	24.7	21.2	66	57
1967	31.3	2.9	20.0	9	64
1968	36.1	26.1	30.1	72	83
1969	33.8	21.4	8.7	63	26
1970	7.9	18.4	(1.6)	233	...
Average 1965-70	32.8%	20.5%	17.8%	63%	54%

* Based on average of year-end assets.

General Motors, therefore, appears to hold a definite edge over its principal competitors by most measures of financial effectiveness. In the sections which follow our goal is to estimate financial results by principal operation for GM and Ford and to compare these results to determine the area and the cause of the substantial profit difference.

Sales and Profits by Major Operation

Since 1965 the auto companies have published sales data for Automotive Operations, Nonautomotive Operations, and Overseas Operations. Profit data, however, are generally not available by operation. In the case of General Motors, therefore, we have assumed that nonautomotive operations yield the same return on sales as total operations. For Ford, we have assumed that the average return on sales for nonautomotive operations published in 1968-69 holds for all other years. We will also calculate the Ford nonautomotive results using the assumption, as for GM, that nonautomotive operations yield the same return on sales as total operations. Nonautomotive operations are discussed at greater length in Part III.

Profit data for overseas operations are stated in the annual report on an after-tax basis; they were converted to pretax profits using the total-company effective tax rate. After subtracting nonautomotive and overseas from total profits, the balance represents profits from automotive operations in North America, including automobiles, trucks, parts, and credit operations. These results are shown in Tables 2 and 3 for the 1965-70 calendar years.

TABLE 2

Pretax Sales and Profits by Major Operation at GM

	Calendar Years					
	1965	1966	1967	1968	1969	1970
Factory unit sales (In thousands):						
North America	6,115	5,551	5,184	5,834	5,761	3,882
Overseas	1,163	1,166	1,087	1,253	1,399	1,426
Total	7,278	6,717	6,271	7,087	7,160	5,308
Dollar sales (In millions):						
Automotive operations						
North America*	$16,305	$15,470	$15,263	$17,760	$18,738	$13,281
Overseas*	2,512	2,562	2,461	2,686	3,026	3,214
Total	$18,817	$18,032	$17,724	$20,446	$21,764	$16,495
Nonautomotive operations	1,917	2,177	2,302	2,309	2,531	2,257
Total	$20,734	$20,209	$20,026	$22,755	$24,295	$18,752
Total overseas including nonautomotive operations (In millions)	$ 2,768	$ 2,871	$ 2,781	$ 2,989	$ 3,378	$ 3,652
Profits before taxes (In millions):						
Automotive operations						
North America*	$ 3,463	$ 2,695	$ 2,490	$ 2,932	$ 2,805	$ 250
Overseas*	250	223	177	234	289	208
Total	$ 3,713	$ 2,918	$ 2,667	$ 3,166	$ 3,094	$ 458
Nonautomotive operations†	379	352	346	358	360	320
Total	$ 4,092	$ 3,270	$ 3,013	$ 3,524	$ 3,454	$ 778
Total overseas including nonautomotive operations (In millions)‡	$ 275	$ 250	$ 200	$ 260	$ 323	$ 236

* Assuming the same percentages of nonautomotive sales and profits for both overseas and North American operations.

† Profit data for nonautomotive operations are not published by GM. The above data assume the same return on sales for automotive and nonautomotive operations.

‡ Net income data are available for overseas operations. The above data assume that overseas operations incurred the same tax rate as the overall corporation.

TABLE 3

Pretax Sales and Profits by Major Operation at Ford

	Calendar Years					
	1965	1966	1967	1968	1969	1970
Factory unit sales (In thousands):						
North America	3,303	3,240	2,434	3,449	3,364	3,214
Overseas	1,184	1,167	1,070	1,204	1,485	1,556
Total	4,487	4,407	3,504	4,653	4,849	4,770
Dollar sales (In millions):						
Automotive operations						
North America*	$ 8,054	$ 8,497	$ 6,713	$ 9,896	$10,093	$ 9,977
Overseas*	2,272	2,397	2,425	2,631	3,187	3,505
Total	$10,326	$10,894	$ 9,138	$12,527	$13,280	$13,482
Nonautomotive operations	1,211	1,346	1,378	1,548	1,476	1,498
Total	$11,537	$12,240	$10,516	$14,075	$14,756	$14,980
Total overseas including nonautomotive operations (In millions):	$ 2,538	$ 2,693	$ 2,734	$ 2,956	$ 3,541	$ 3,895
Profits before taxes (In millions):						
Automotive operations						
North America*	$ 1,110	$ 913	$ 10	$ 950	$ 744	$ 704
Overseas*	142	195	46	238	304	218
Total	$ 1,252	$ 1,108	$ 56	$ 1,188	$ 1,048	$ 922
Nonautomotive operations†	68	75	77	103	67	84
Total	$ 1,320	$ 1,183	$ 133	$ 1,291	$ 1,115	$ 1,006
Total overseas including nonautomotive operations (In millions)‡	$ 158	$ 213	$ 65	$ 258	$ 323	$ 242

* Assuming the same percentages of nonautomotive sales and profits for both overseas and North American operations.

† Nonautomotive profits were published by Ford only for 1968 and 1969. For other years the above data assume the same return on sales as the average of 1968 and 1969 (5.6%).

‡ Net income data are available for overseas operations. The above data assume that overseas operations incurred the same tax rate as the overall corporation.

Quarterly sales and profit data for each of the years were then obtained. We allocated nonautomotive sales and profits equally among each calendar year quarter (because of the variety of operations it was assumed that nonautomotive operations do not incur the heavy cyclical swings of automotive operations). Since overseas dollar sales and profits are available on an annual basis only but quarterly unit sales are available from quarterly financial statements, we allocated overseas sales and profit data on the basis of these quarterly unit sales. In view of the significant variations in quarterly unit sales, we believed this to be a more accurate representation of quarterly results than that obtained arbitrarily with an equal distribution by quarter. For each quarter the balance represents North American car and truck operations. At this point we have obtained quarterly sales and profit data for each of the major operations of General Motors and Ford.

Conversion to model years

Calendar year data are stated at two different basic levels of pricing, design, and labor rates because they cover two different models produced within the same calendar year. It is necessary, of course, to obtain financial data which are internally consistent if we are to obtain accurate results by car line. Therefore, we decided to use financial data which most nearly approximated product cycle or model years. For the purpose of this discussion, a model year is defined as the 12-month period beginning July 1 so it will coincide

with the timing of quarterly financial reports. Results by major operation for the 1969 model year are shown in Table 4.[3/]

TABLE 4

Sales and Profits by Operation for the 1969 Model Year
(In Millions)

	GM			Ford		
	Sales	Pretax Profits	Pretax Margin	Sales	Pretax Profits	Pretax Margin
Automotive operations						
North America	$18,492	$2,909	15.7%	$ 9,674	$ 868	9.0%
Overseas	2,882	265	9.2	2,750	256	9.3
Total	$21,374	$3,174	14.8%	$12,424	$1,124	9.0%
Nonautomotive operations	2,421	359	14.8	1,512	85	5.6
Total	$23,795	$3,533	14.8%	$13,936	$1,209	8.7%

As shown above, Ford's pretax return on sales for the 1969 model year is 8.7 per cent, compared with 14.8 per cent for GM. We are now able to quantify the difference in profit performance. If Ford had earned 14.8 per cent on sales, as GM did, its pretax profits would

3/ The reader should note that 1969 will be the basis of our analysis for the rest of this study. We chose 1969 because it is the latest year for which detailed car line volume and option data essential for calculation of mix differences are available at this time.

have been $2,063 million, which is $854 million higher than its actual profits of $1,209 million. Our next task is to explain where this difference occurs, and why.

II

VARIABLE PROFITS

In this section the various techniques used to obtain further details on automotive operations in North America are explained. First, fixed and variable costs are derived by means of linear regressions, and then we attempt to obtain the relative profit contribution of major car lines.

Fixed and Variable Costs

Variable profits are defined as revenue minus variable costs or, alternatively, actual profits before taxes, plus fixed costs. The following technique is used to obtain these fixed and variable components.

First, quarterly dollar sales are plotted against profits before taxes. A simple linear regression for these two variables is calculated and then fit with a least-squares line through the intersecting points. The slope of the line obtained represents the average variable profit rate for the firm, i.e., the incremental profit contribution expressed as a percentage of sales. In other words, it shows variances in profits which result from variations in sales. The point intersecting the vertical axis can be taken as an estimate of average fixed costs. It should be noted, however, that these fixed costs do not represent a shut-down

minimum level but rather the continuing fixed costs (including the fixed portion of semivariable costs) incurred during normal operating conditions. An example of this regression is shown in Figure 1.

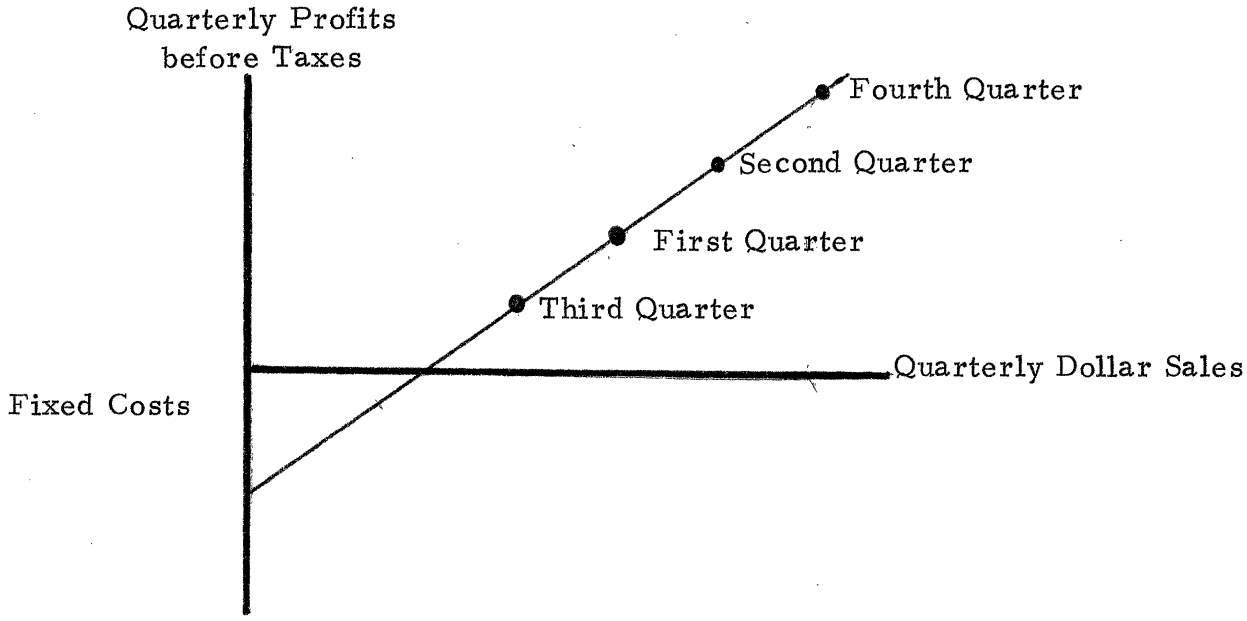

Fig. 1. Quarterly profits before taxes versus quarterly dollar sales.

Applying the technique illustrated above to General Motors, the quarterly profits before taxes and dollar sales for each model year from 1965 to 1970 are plotted; the regression derived from these points yields preliminary estimates of fixed and variable costs for each model year. A discussion of the validity of the regression is provided in the Appendix. Because there are only four observations for each year, the annual results are very strongly influenced by the position of each observation--and particularly by that of the third quarter. Any extraordinary items, such as large launching costs resulting from the introduction of new car lines, or temporary strikes, have a great

deal of influence on the slope of the line and the intercept and do not represent normal operating conditions. To correct data to a more normal long-term level, the logarithms of the intercepts for each of ten years were plotted. A least-squares line was fit to obtain the long-run growth function of fixed costs. From this second regression new estimates of annual fixed costs were obtained. A comparison of our preliminary estimates with the revised fixed cost data appears in Table 5. These fixed costs were then added to the actual profit before taxes,

TABLE 5

GM Fixed Costs, 1965-70
(In Millions)

Model Year	Preliminary Estimate	Revised Estimate
1965	$ 2,210	$ 2,343
1966	2,571	2,586
1967	3,501*	2,854
1968	3,411	3,151
1969	3,448	3,478
1970	3,716	3,839

* This data point was ignored because of the unusual loss in the third quarter of 1966. The subject is discussed in greater detail in the Appendix.

thus obtaining a new set of variable profits; for the 1965-70 period, General Motors' variable profit ranged from 34.4 per cent to 37.5 per cent of sales. Having obtained total dollar results for North American automotive operations, we can now calculate dollar sales,

variable costs, variable profits, fixed costs, and pretax profits for an average vehicle by simply dividing total results by factory unit sales. Total results and average vehicle results are shown in Table 6.

Variable Profits for Major Product Lines

Separation of car and truck results

The results in Table 6 identify sales, profits, and costs for an average North American unit--including cars and trucks. We must first eliminate trucks, therefore, in order to obtain car line data. Truck prices and volumes, however, are not published in enough detail to facilitate separating trucks from cars. In addition, the prices of optional equipment and their installation rates for trucks are unavailable. So the only reasonable alternative was to estimate the total value of all trucks within each firm; therefore, the relationship of the total wholesale value of trucks to cars (as published in the Automotive News Almanac) was used to estimate average dollar sales for trucks.[4/]

Profits from truck manufacturing operations also are not available. In order to demonstrate fully the profit effect of differences in the mix of operations, we believe that it would be useful to attempt to quantify the profitability of trucks--or at least to show the general

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4/ Automotive News, 1970 Almanac (Detroit: Slocum Publishing Co., 1970), p. 8.

TABLE 6

North American Car and Truck Operations at GM

	Model Years*					
	1965	1966	1967	1968	1969	1970
	Total Results (In Millions)					
Dollar sales	$13,918	$16,137	$14,734	$16,473	$18,492	$18,264
Variable costs	8,704	10,398	9,584	10,567	12,105	11,980
Variable profits	5,214	5,739	5,150	5,906	6,387	6,284
Fixed costs	2,343	2,586	2,854	3,151	3,478	3,839
Pretax profits	$ 2,871	$ 3,153	$ 2,296	$ 2,755	$ 2,909	$ 2,445
Variable profit rate	37.5%	35.6%	35.0%	35.9%	34.5%	34.4%
	Average Vehicle Results					
Dollar sales	$ 2,623	$ 2,721	$ 2,903	$ 3,005	$ 3,139	$ 3,346
Variable costs	1,640	1,753	1,888	1,928	2,055	2,195
Variable profits	983	968	1,015	1,077	1,084	1,151
Fixed costs	442	436	562	575	590	703
Pretax profits	$ 541	$ 532	$ 453	$ 502	$ 494	$ 448
Unit sales (In thousands)	5,307	5,931	5,075	5,481	5,891	5,458

* Beginning July 1 of the prior year.

direction of truck profits when compared to cars--even on a very subjective basis. As a result of conversations with industry analysts, and after analysis of the financial statements of truck manufacturing companies, we concluded that truck operations were less profitable than car operations in the 1969 model year; arbitrarily we decided that truck unit profits were 75 per cent as high as car profits. The results of these estimates are shown in Table 7.

TABLE 7

GM Car and Truck Results
for the 1969 Model Year

	Volume (In thousands)	Revenue Per Unit	Variable Cost Per Unit	Variable Profit Per Unit
Cars	4,979	$3,075	$1,949	$1,126
Trucks	912	3,490	2,645	845
Total/Average	5,891	$3,139	$2,055	$1,084

On the basis of our estimates for truck revenues, a new average revenue was obtained for cars. It is clear that this series of estimates could lead to some errors in the distribution of sales and profits between cars and trucks. Trucks, however, represented less than 15 per cent of GM's North American unit volume in 1969. This assumption also has little effect on our analysis of the product mix.

Volume and mix by major car line

We then noted the volume achieved by each car line during the model year. Since profits are determined by the number of units sold by the factories (factory unit sales), these data were collected for each major car line (e.g., Chevrolet, Chevy II, Buick Special, etc.), and the model mix within car lines (e.g., Buick Special--Deluxe, Skylark, Skylark Custom, etc.) was obtained.

Prices for each car line

For each car line and each major series, dealer cost (i.e., wholesale revenue) was used for base vehicles and options.[5/] A representative high-volume model (i.e., four-door sedan or two-door hardtop) was selected subjectively if required. The prices were then averaged at the appropriate production mix previously determined to obtain an average for each major series; they represent "bare vehicle [without options] prices."

Installation rates for seven major options (V-8 engines, power steering, power brakes, AM radio, air conditioning, vinyl top, and automatic transmission) were obtained from Ward's and the Automotive News Almanac. We multiplied these rates by the dealer cost of each option--after adjustment for standard equipment if necessary.

5/ These data were obtained from Automotive Invoice Services Company, 222 W. Adams, Chicago, Illinois.

Bare vehicle and option prices were then added and averaged, again using the appropriate mix to obtain an average estimate for each car line. Next the car lines were combined to obtain an average revenue estimate for General Motors.

As expected, this average revenue was somewhat below the average calculated earlier in Table 6. The above data, indeed, took into account only seven major options and included no allocation for profits resulting from the sale of parts and accessories. The average figure obtained earlier, however, included all sales resulting from automotive operations. The prices obtained above were therefore increased by the percentage required to reconcile the two sets of data. It should be noted that the required adjustment was only 6 per cent of the total; therefore, 94 per cent of total revenue was explicitly accounted for.

Variable costs and profits

Variable cost information is, of course, not available. An estimate of variable cost was previously shown for an average car (Table 6). This variable cost must now be allocated to each car line on a rational basis. Then we will subtract the variable cost from the revenue calculated above to obtain variable profits by car line. Variable costs consist essentially of direct material, direct labor, and variable overhead--direct material being by far the largest of the three elements. This was clearly evident in data from the 1968 Senate hearings in which the average material cost of a 1966 model Ford was shown to represent 88 per cent of unit standard cost, as Table 8 illustrates:

TABLE 8

1966 Ford Car Unit Costs

Cost Element	Average Ford Car	Percentage of Unit Standard Cost
Material	$1,578.24	88.0%
Direct labor	61.74	3.5
Manufacturing overhead	153.08	8.5
Unit standard cost	$1,793.06	100.0%

One of the relative measures of the direct material and labor content of each car is weight. Weight data are available for each major car line and are generally representative of the variable cost of a vehicle. This assumption was confirmed by an analysis of the unit cost data which was published in the Congressional Record in 1968.[6/] Indeed, unit cost data were published for the various models in the 1966 Ford car line; these unit costs ranged from $1,549 for a custom two-door sedan to $2,158 for a Galaxie 500 two-door 7-liter convertible.

We tested our assumption that variable costs vary with weight by regressing unit vehicle cost on weight. From the results we concluded

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6/ U.S., Congress, Senate, Senator Nelson speaking on Automaker's Cost Data, 90th Cong., 2d sess., Sept. 25, 1968, Congressional Record, CXIV, 28136.

that weight is an acceptable proxy variable for unit cost. The correlation coefficient was approximately .9 and the regression coefficients were significant at greater than the .001 per cent level. (Other statistics relative to the regression are discussed in the Appendix.) Thus the assumption that weight data are representative of variable cost is valid.

As a result we calculated an average weight for General Motors' cars and matched this with the estimate of average variable costs. Variable costs were then allocated to all car lines on the basis of weight.

Variable profits are simply the results of unit revenue less unit variable costs. These results for GM in the 1969 model year are shown in Table 9.

Profile of the Results: The Variable Profit Rate

Having obtained variable profits by car line, we wanted to analyze the relationship between sales and profits. Therefore unit revenue and variable profits were plotted on a chart and a third linear regression was calculated.

The "fit" of the line was good--its multiple correlation coefficient was .96. The formula obtained is the following:

$$\text{Variable Profit} = (.67 \times \text{Revenue}) \quad \$-830$$

The only vehicle which showed a significant deviation from the line was the Corvette. This discrepancy may be explained by the fact that the Corvette has a fiberglass body which weighs less but probably costs

TABLE 9

Unit Revenue, Variable Cost, and Profit
at GM for the 1969 Model Year

	Revenue		Variable Costs	Variable Profit	Percentage of Total Volume	Weight (Pounds)
	Bare Vehicle	Including Options				
Chevrolet:						
Corvair	$1,806	$2,045	$1,342	$ 703	0.1%	2,513
Chevy II	1,773	2,112	1,555	557	4.5	2,911
Camaro	1,998	2,443	1,532	911	3.8	2,869
Chevelle	1,956	2,495	1,664	831	8.2	3,115
Chevrolet	2,137	2,828	1,946	882	22.0	3,643
Corvette	3,462	3,924	1,651	2,273	0.6	3,091
Buick:						
Special	$2,215	$2,937	$1,804	$1,133	3.7%	3,337
Full-size	2,769	3,617	2,222	1,395	7.8	4,160
Riviera	3,380	4,081	2,241	1,840	1.0	4,195
Oldsmobile:						
F-85	$2,181	$2,940	$1,770	$1,170	4.8%	3,314
Full-size	2,718	3,498	2,248	1,250	7.0	4,208
Toronado	3,471	4,162	2,294	1,868	0.5	4,295
Pontiac:						
Tempest	$2,189	$2,825	$1,793	$1,032	5.4%	3,357
Full-size	2,505	3,338	2,150	1,188	9.7	4,026
Firebird	2,091	2,658	1,645	1,013	1.4	3,080
Cadillac	$4,336	$5,206	$2,477	$2,729	4.0%	4,637
Average GM car		$3,075	$1,949	$1,126	84.5%	3,643
Average truck		$3,490	$2,645	$ 845	15.5%	
Average car and truck		$3,139	$2,055	$1,084	100.0%	

more than standard steel bodies. Since the estimate of variable cost was based on weight, the Corvette's variable cost was underestimated. Furthermore, the independent rear suspension of the Corvette is also likely to raise the variable cost of the vehicle.

Because of the probable inaccuracy of our cost estimate for the Corvette, we ran the same regression excluding that vehicle. The subsequent results were substantially better statistically; the resulting formula is:

$$\text{Variable Profit} = (.63 \times \text{Revenue}) \quad \$-746$$

This formula yields the following results for our revenue range:

TABLE 10

Relationship between Variable Profit and Revenue at GM for the 1969 Model Year

Unit Revenue	Variable Profit	Variable Profit Rate
$2,000	$ 514	25.7%
3,000	1,144	38.1
4,000	1,774	44.3
5,000	2,404	48.1

The results in Table 10 show the dramatic increase in variable profit rate as unit revenue increases. Some of these differences, of course, may be required to offset low volume and high unit asset requirements.

Validation of the results

The above results were again tested against the 1966 Ford data mentioned earlier. A regression of actual revenues and profits for the 1966 Ford (excluding station wagons and convertibles) yielded the following formula:

$$\text{Variable Profit} = (.50 \times \text{Revenue}) \quad -\$639$$

This regression had a multiple correlation coefficient greater than .99. An analysis of the regression is found in the Appendix. For the $2,000-$5,000 range we obtain from the formula the following results:

TABLE 11

Relationship between Variable Profit and Revenue at Ford for the 1966 Model Year

Unit Revenue	Variable Profit	Variable Profit Rate
$2,000	$ 356	17.8%
3,000	854	28.5
4,000	1,352	33.8
5,000	1,850	37.0

Variable profit rates rise substantially as unit revenue increases; in fact, the variable profit rate more than doubles as unit revenue moves from $2,000 to $5,000. This test confirms the data obtained earlier for General Motors.

There remain some differences between the Ford and GM results. These differences result from several factors, some of which are explained below:

- The two regression lines cover two different companies, Ford and General Motors.
- The Ford data are for 1966 models whereas GM data are for 1969 models.
- The GM data include options and an allocation for parts revenue and profit; the Ford data are for bare vehicles only.
- The Ford unit costs are not variable costs because they include an allocation for some fixed costs as well as nonassembly division profits as costs. A true Ford variable profit would therefore be higher than that which is shown in Table 10.
- The Ford data cover various models within one car line. The GM data cover a full range of vehicles from the Corvair to the Cadillac.

There are probably other differences. The results, however, are sufficiently clear for our analysis. Indeed, both equations yield variable profit rates which approximately double as one goes from a revenue of $2,000 to $5,000.

PART III

ANALYSIS OF PROFIT DIFFERENCES

We now turn our attention to an analysis of the factors which contribute to the differences in profit performance between Ford and General Motors.

Mix of Major Operations

Earlier in this study we noted that the difference in profit performance between Ford and GM was $854 million in the 1969 model year. We obtained this result by taking GM's pretax sales margin (14.8 per cent) and applying it to Ford's dollar sales; on this basis Ford's profits would have amounted to $2,063 million, or $854 million more than Ford's actual profits of $1,209 million.

If, however, we apply GM's margin by principal operation to Ford's sales, total profits would be only $1,996 million, $67 million less than the $2,063 million figure. The reason for the $67 million difference is that General Motors has a different sales mix, with a higher percentage of high-profit North American operations and a lower ratio of overseas and nonautomotive operations. The $67 million difference is explained, therefore, by a difference in the mix of major operations between Ford and General Motors. Table 12 illustrates Ford's sales mix.

TABLE 12

Sales and Profits by Operation at Ford
(In Millions)

Operation	Ford Sales	Pretax Profits		Sales Margins	
		Actual	At GM Sales Margins	Actual	At GM Sales Margins
Automotive					
North America	$ 9,674	$ 868	$1,519	9.0%	15.7%
Overseas	2,750	256	253	9.3	9.2
Nonautomotive	1,512	85	224	5.6	14.8
Subtotal	$13,936	$ 1,209	$1,996*	8.7%	14.8%
Mix of operations	...	...	67	...	...
Total	$13,936	$ 1,209	$2,063	8.7%	14.8%

* Represents a 14.3% sales margin.

Utilizing data from Table 12 we can break down the estimated difference in profit performance by operation for Ford and GM. These results are summarized in Table 13:

TABLE 13

Profit Performance by Operation at Ford and GM
(In Millions)

	Pretax Profits
Ford--actual profits	$1,209
Ford--profits with GM margin	2,063
Variance	$ 854
GM Better/(Worse) than Ford:	
Automotive operations	
North America	$ 651
Overseas	(3)
Nonautomotive operations	139
Mix of operations	67
Total	$ 854

Profit Differences within Each Operation

In the sections which follow we will analyze each of these profit differences individually. We will begin our analysis with the relatively simple areas of overseas and nonautomotive operations and then proceed with the more complex car and truck operations in North America.

Automotive operations overseas

Overseas operations for Ford and GM are extremely similar, both in terms of sales and in terms of profits. In the 1969 model year Ford had a $3 million profit advantage over GM. This advantage reflected the fact that Ford's sales margin--at 9.3 per cent--was 0.1 point higher than GM's. So there appears to be little difference between Ford and GM in the area of automotive operations overseas.

Nonautomotive operations

Our assumption up to this point has been that General Motors' nonautomotive operations earn the same pretax margin on sales as its automotive operations. This assumption was made for two principal reasons: (1) the lack of information on GM's nonautomotive profits and (2) the great variety of GM's nonautomotive operations made estimates of profitability impossible in view of the variety of industries in which nonautomotive products compete. The solution chosen, therefore, appeared to be the least arbitrary.

Ford, on the other hand, published its nonautomotive profits for the 1968 and 1969 calendar years. Table 14 presents a comparison of the relative profitability of nonautomotive operations for Ford and GM.

TABLE 14

Profitability of Nonautomotive Operations at Ford and GM
(In Millions)

Nonautomotive Operations	1969 Model Year		
	Sales	Pretax Profit	Profit Margin
Ford	$1,512	$ 85	5.6%
Ford at GM margin	1,512	224	14.8
Difference		$139	9.2 pts.

As shown in Table 14, we estimated that Ford earned $85 million before taxes on nonautomotive operations in the 1969 model year and had sales of $1,512 million, for a return on sales of 5.6 per cent. At GM's margin of 14.8 per cent Ford would have earned an additional $139 million, for a total profit of $224 million on nonautomotive operations.

If we assume that Ford's return on nonautomotive operations is the same as its return on total operations (the assumption that we have used to estimate GM's data), the difference between Ford's pretax profits and the additional profits based on GM's margin drops from $139 million to $92 million. (The balance of $47 million would then go to North American operations to increase the profit variance between Ford and GM, as shown in Table 13, from $651 million to $698 million.)

These profit differences between Ford and GM in the nonautomotive area are substantial, but not unexpected. It has been reported that Philco Corporation, which represents a large percentage of Ford's

nonautomotive sales, has been a losing operation for most years since its acquisition by Ford in the early 1960s. For example, Business Week reported that:

> The long-ailing operation is expected to show a profit this year for only the second time since it was acquired by Ford.7/

With large sales and no profits, Philco has had the effect of substantially reducing Ford's return on sales in nonautomotive operations.

Of course it is probable that GM's nonautomotive sales have a higher or lower return than that which is shown in this study. If we keep in mind that the total profit difference for all operations must remain the same, this means that perhaps a portion of the profit difference attributed to nonautomotive operations should be attributed to North American operations. This possibility, however, does not affect the validity of our findings; in all events a large profit difference in the nonautomotive area is to be expected because of the Philco losses.

North American car and truck operations

As shown earlier, the largest difference in profit performance between Ford and GM occurs in North American car and truck operations. This difference was estimated at $651 million in Table 13. Our analysis of this difference is divided into three principal parts: (1) an analysis of profit differences resulting from differences in mix among vehicle

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7/ Business Week, Oct. 2, 1971, p. 75.

lines, (2) an analysis of revenue effects, and (3) an analysis of other major factors contributing to this profit difference.

Vehicle sales mix and profit performance. We have already seen that GM's mix is substantially stronger than that of its competitors, and Table 15 supports this observation.

TABLE 15

U.S. Car Production for the 1966 Model Year
(Excluding Imports)

Retail Price	Industry		GM		GM's Share of Total Industry Volume
	Volume*	Percentage	Volume*	Percentage	
Below $2,000	98.9	1.2%	0	0%	0%
$2,001-$3,000	5,598.9	66.1	2,822.8	61.7	50.4
$3,001-$4,000	1,976.9	23.3	1,160.0	25.3	58.7
$4,001-$5,000	475.7	5.6	369.5	8.1 } 13.0	77.7 } 74.
Above $5,000	323.1	3.8	223.2	4.9 }	69.1 }
Total	8,473.5	100.0%	4,575.5	100.0%	54.0%

* In thousands.

Table 15 also shows that GM's market share increases substantially as one moves up the price scale; indeed, GM's share of the over-$4,000 class, although it represents only 13 per cent of GM's total volume, is 74.2 per cent. Because variable profits increase rapidly as prices rise, its strong mix provides GM with a significant profit advantage over its competitors.

Our purpose in this section is to quantify the profit effect of this mix difference between Ford and GM. First we listed the principal GM cars, their respective variable profits, and their percentage contribution (mix) to total vehicle volume. We then averaged these data to arrive at an average profit for cars and trucks. The results are shown in Table 16.

Opposite the GM cars we listed the Ford cars which compete in the same segment of the market. The cars are matched on the basis of the bare vehicle wholesale price of the lowest-priced model in each car line. Next, we gave the Ford cars the same variable profit as the comparable GM car and listed their percentage contribution to total Ford volume. For example, the Falcon is shown opposite the Chevy II; both cars are assumed to have the same variable profit of $557. The Chevy II contributes 4.5 per cent of the total GM volume and the Falcon represents 4 per cent of the Ford volume.

Having matched the Ford cars with their GM counterparts, we averaged these data, and the results can be seen in Table 16.

Assuming that Ford and GM have the same variable profit for each car line, the effect of mix alone results in additional profits to GM of $102 per unit for comparable cars. GM also has some car lines for which Ford has no substitute, such as the Buicks, Oldsmobiles, and the Corvette. Because these cars compete in the higher price bracket, they increase GM's average profit per car by $69 and give GM a $171 advantage per car. Trucks are also assumed to have the same profits

TABLE 16

Effect of Vehicle Mix in North American Car and Truck Operations

	GM			Ford		
	Car	Variable Profit	Percentage of GM Volume	Car	Variable Profit	Percentage of Ford Volume
Competing cars:						
	Chevy II	$ 557	4.5%	Falcon	$ 557	4.0%
	Camaro	911	3.8	Mustang	911	9.5
	Chevelle	831	8.2	Fairlane	831	11.8
	Chevrolet	882	22.0	Ford	882	31.1
	Corvair	703	0.1	Maverick	703	2.7
	Tempest	1,032	5.4	Montego	1,032	4.6
	Pontiac	1,188	9.7	Mercury	1,188	4.9
	Firebird	1,013	1.4	Cougar	1,013	3.9
	Cadillac	2,729	4.0	Lincoln	2,729	1.9
	Riviera	1,840	1.0	Thunder-bird	1,840	1.6
Average for competing cars		$1,057	60.1%		$ 955	76.0%
Noncompeting cars:						
	Corvette	$2,273	0.6%	...	...	...
	Special	1,133	3.7	...	...	...
	Buick	1,395	7.8	...	...	...
	F-85	1,170	4.8	...	...	...
	Olds	1,250	7.0	...	...	...
	Toronado	1,868	0.5	...	...	...
Average for non-competing cars		$1,301	24.4%		...	...
Average car		$1,126	84.5%		$ 955	76.0%
Average truck		$ 845	15.5%		$ 845	24.0%
Average car and truck		$1,084	100.0%		$ 929	100.0%

for both Ford and GM. The net result is that Ford's unit profits are $155 lower than GM's because of mix differences for all vehicles. This difference in profits results from: (1) a lower average wholesale revenue for Ford, and (2) a lower average variable profit rate for Ford.

The profit difference of $155 per average unit between Ford and GM has a total profit effect of $502 million at the Ford volume of 3,236,000 units in the 1969 model year. Of this amount, $330 million results from GM's mix advantage on comparable cars and $223 million can be attributed to GM's unique vehicles for which Ford has no direct substitute. These amounts are offset partially by the effect of truck mix ($51 million).

In other words, even if Ford's profits by car line were the same as GM's, its total profits would still be $502 million lower than the level required to yield the same sales margin as GM. Of the $651 million difference in North American car and truck operations, therefore, $502 million, or 77.1 per cent, is explained by mix factors alone.

Other revenue effects. The reader should note that, in the above analysis, all factors were held constant except for mix. In other words, by using the same variable profit by car line for Ford and GM we also assumed that prices and variable costs are the same for both companies. In addition, this analysis measured differences in mix among vehicles, but not within vehicle lines (i.e., the effect of various models within each car line). We did not measure mix differences within car lines primarily because we do not have enough information on body style mix

or equipment level by model. Therefore, we also assumed the same mix within car lines for Ford and GM.

However, we do know that Ford has a relatively higher unit revenue than GM after taking mix into account; indeed, if we again give each Ford car the same revenue as its GM counterpart and calculate an average at the Ford mix, the average revenue obtained is lower than Ford's actual revenue, as is shown in Table 17.

TABLE 17

Unit Revenue at Ford and GM

	Average Car and Truck Revenue	Ford Over/ (Under) GM
GM actual	$3,139	
Ford (at GM prices)	2,944	$(195)
Ford actual	2,989	45

This difference in unit revenue of $45 ($2,989-2,944) may be the result of three principal factors: differences in pricing, mix within vehicles, and option installation rates. Because of the lack of data, we are unable to delineate the effect of these three factors, or to quantify their influence on profit with precision. One of the principal difficulties lies in the fact that these three factors are interrelated; a higher price may be designed to compensate for a higher level of standard equipment which, in turn, affects the option rate and mix-within calculations. Another problem is

that the influence of pricing passes straight through to profits, whereas the mix-within and option rate effects are subject to the variable profit rate.

We can, however, estimate a probable range. The maximum profit effect is $45 per unit, or $146 million at the Ford volume; the minimum is probably in the neighborhood of $50 million (using GM's variable profit rate of 34.5 per cent). We subjectively selected $100 million as the probable profit effect of the three aforementioned factors. This estimated profit difference simply results from the fact that Ford has a relatively higher revenue than GM does.

A further test seemed to generally confirm this $100 million profit estimate. We attempted to estimate a pure pricing variance by comparing the average revenue on the lowest-price bare vehicle with comparable cars at the same mix. The advantage of using the lowest-price model in a pricing calculation is that cars tend to have the same general level of equipment--i.e., the minimum required to compete in that price class. Revenue differences are, therefore, more likely to reflect actual price differences rather than equipment differences.

The Ford revenue obtained as a result of the comparison was $21 higher than GM's revenue. If we assume that the pricing policy on base models applies to higher-priced models as well, this pricing variance of $21 has a profit effect of about $68 million at the Ford volume. The balance of $32 million would then be attributed to mix-within and option rate differences--or approximately the balance of $78 million ($146-68) at a variable profit rate of about 35 per cent. We therefore believe that the estimate of $100 million is reasonable.

Other reasons for profit differences. We have explained $402 million of the $651 million profit difference between Ford and GM. Now we propose to look at a few of the other profit differences which are readily discernible from annual reports and which account for some of the $249 million of profit difference remaining in North American operations. For the sake of consistency we will use average data from the 1968 and 1969 calendar years to arrive at 1969 model year results. Because we have defined North American car and truck operations as the balance which remains after removing overseas and nonautomotive operations, we have implicitly assumed that nonoperating income and expenses (such as interest income or income from finance companies) are included in North American operations. Calculation of profit differences with nonoperating items shown as a separate activity does not significantly affect the results.

Other income (net of expense)

GM's other income (principally interest income) is substantially higher than Ford's, as Table 18 indicates for the 1969 model year:

TABLE 18

Other Income at Ford and GM

	GM	Ford	Ford Under GM
Other income			
Amount (In millions)	$ 90	$ 9	$ 81
Percentage of sales	0.378%	0.065%	.313 pts.

If we apply the above difference in percentage of sales to Ford's North American car and truck sales of $9,674 million, we obtain a profit difference of $30 million.

Vertical integration

Another significant profit difference can be attributed to vertical integration. It is a difference, however, which is difficult to estimate; we can only hope to obtain an approximation of the profit difference resulting from the different levels of vertical integration. Both Ford and GM publish the percentage of sales which they use to pay suppliers. The average amount in 1968 and 1969 was 46.5 per cent for GM and 57.3 per cent for Ford. If Ford had the same level of integration as GM, it would be able to reduce its purchases from suppliers by $1,045 million. Let us assume that GM would not integrate operations if doing so would lower its return on sales of 15.7 per cent on North American operations. At the rate of 15.7 per cent, Ford's profits would be $164 million higher ($1,045 x 15.7%) if it were able to reach GM's level of integration. Of course this represents an ideal long-term situation and not one directly applicable to the 1969 model year. It does, however, provide us with an approximation of the magnitude of the profit difference caused by vertical integration.

A preliminary analysis of Ford's unit profits shows that Ford's fixed costs per unit are substantially lower than GM's; we believe that the fixed costs are lower mainly because of the difference in integration. In other words, with greater integration Ford would be substituting its own labor and capital for that of the supplier. The net effect would be to reduce variable costs and increase fixed costs and profits.

Tooling amortization

General Motors' tooling amortization expense is higher than Ford's in absolute terms and as a percentage of sales, as Table 19 indicates for the 1969 model year.

TABLE 19

Tooling Amortization Expenses at Ford and GM

Expense	GM	Ford	Ford Under GM
Tooling amortization			
Amount (In millions)	$873	$378	$495
Percentage of sales	3.67%	2.71%	.96 pts.

Applying the difference shown above to Ford's North American car and truck sales, we obtain a difference of $93 million in profit performance. This difference appears to result primarily from the fact that Ford has substantially lower tooling expenditures per dollar of sales when compared to GM.

Summary of Profit Differences

Let us summarize the results of our analysis. Earlier in this study we identified a difference in profit performance of $854 million between Ford and GM. Our analysis has identified the following factors which account for this difference in the 1969 model year:

TABLE 20

Explanation of Profit Differences between Ford and GM
(In Millions)

Operation	GM Better/(Worse) than Ford
North American car and truck:	
Mix among competing cars	$330
Mix among noncompeting cars	223
Mix of cars and trucks	(51)
Total mix among vehicles	$502
Pricing	(68)
Mix within vehicles and option rates	(32)
Interest income (net)	30
Vertical integration	164
Tooling amortization	(93)
Other (unexplained)	148
Total--North America	$651
Nonautomotive	139
Overseas car and truck	(3)
Mix of operations	67
Total profit difference	$854

Three major items appear to account for most of the profit difference of $854 million between Ford and GM. They are: mix among vehicles ($502 million), vertical integration ($164 million), and non-automotive operations ($139 million). GM's principal advantage over Ford, therefore, appears to lie in marketing superiority--i.e., an ability to sell more vehicles in the high-price bracket. GM is well-established in this market (Pontiac, Buick, Oldsmobile, Cadillac); it is a market segment which is difficult for other companies to enter because it seems

to be characterized by strong customer loyalty and requires heavy investments for unique vehicles over a relatively low-volume market.

IV

CONCLUSION

We have demonstrated a technique for estimating financial results by principal operation and variable profits by car line. We can now obtain a further breakdown of financial results by allocating fixed costs (based on volume) to unit variable profits, and by grouping the vehicles by division. This breakdown for General Motors is shown in Table 21:

TABLE 21

GM Results by Division for the 1969 Model Year
(In Millions)

Operation	Sales	Pretax Profits	Pretax Margin
North American			
Chevrolet	$ 6,129	$ 620	10.1%
Buick	2,549	561	22.0
Oldsmobile	2,400	473	19.7
Pontiac	3,032	516	17.0
Cadillac	1,208	494	40.9
Trucks	3,174	245	7.7
Total	$18,492	$2,909	15.7%
Overseas	2,882	265	9.2
Total--automotive	$21,374	$3,174	14.8%
Nonautomotive	2,421	359	14.8
Total	$23,795	$3,533	14.8%

The table obviously represents a simplified estimation of actual results for General Motors. Indeed, it only takes into account the

major end-product divisions, which include an allocation for credit operations, parts operations, and manufacturing facilities common to the car and truck group (such as Saginaw Steering Gear). However, these results will prove useful to industry analysts since they provide some insight into the profitability of car lines as prices vary and represent a first step toward estimating divisional profit performance.

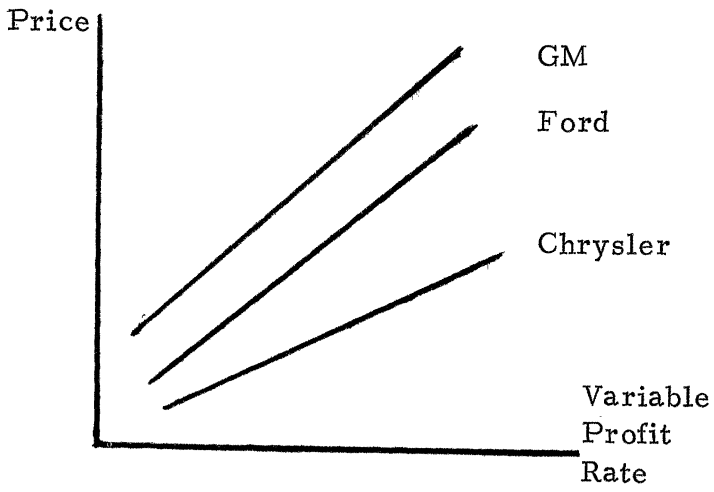
In addition to the above results we have provided a method for estimating the fixed and variable cost structure of the firms and for estimating variable profits by vehicle line. Furthermore, some interesting insights into the relationship between sales revenue and variable profits have been obtained.

Finally, we quantified the major factors which account for the substantial difference in profit performance between Ford and General Motors. Our analysis highlighted the importance of mix and its contribution to profits. Other differences such as differences in design costs, marketing costs, and economies of scale were not quantified. We believe, however, that their total effect is relatively minor. In fact, it is probable that Ford has already reached an optimum level of operation which takes maximum advantage of economies of scale. While it seems that there are no economies of scale beyond the volume achieved by

Ford, there is also no evidence that there are diseconomies of scale beyond that volume.

There is still much to be studied in the area of economies of scale. A complete discussion should, of course, include comparisons of variable profits for comparable vehicles as well as comparisons of investment requirements. These topics will be the subject of the next section of this study. Specifically, we plan to analyze the differences in slope of the linear regressions of prices and variable profit rates by car line.

The slope of these lines for Chrysler and Ford will shed some light on the extent to which economies of scale are operative. This slope must be analyzed not only in relation to General Motors but also on a year-by-year basis to determine if changes take place in high- or low-volume years. To illustrate:



If we should discover, for example, that the slope of the price/variable profit rate regression is parallel for the three firms, this might indicate

that there are no economies of scale beyond the level achieved by Chrysler. Differences in the intercept of the lines could simply be due to differences in integration level. Likewise, the behavior of these regressions at varying volume levels and constant mix should yield some answers to the questions of economies of scale and behavior of cost curves.

Finally, an important area to be investigated is that of asset and investment requirements. Estimates of asset requirements at varying volume levels, and of divisional asset requirements, should reveal a good deal about the performance and behavior of the firms and their principal operations.

APPENDIX

Investigation of Regressions

At several stages in the analysis of this project regression was used to establish relationships between sets of variables. This appendix is designed to verify the validity of these regressions.

Regression was first used to determine the quarterly fixed costs for each model year; these fixed costs were then corrected to a more normal long-term level by determining their long-run growth function. Finally, the relationship between sales and profits by car line was examined. Each use of regression will be reviewed.

As discussed in the paper, the regression used to determine quarterly fixed costs for each model year consists of only four points, and the annual results were strongly influenced by the position of the third quarter point. It is impossible to make any meaningful assertions concerning the validity of the regression model from only four data points except for the fact that the t-statistic for the regression was sufficiently large to assure us that the slope is not zero. Furthermore, the intercepts (fixed costs) were significant at the 1 per cent level. In fact, all of the regressions used were significant at least at the 1 per cent level or below.

The regression used to determine long-run growth of fixed costs had more data and did lend itself to examination for appropriateness of the regression model. Although the data presented in the paper are for model years 1965-70, the regression was based on data from model years 1962-70. An examination of residuals was performed on the first regression, years 1962-70. Figure 1A shows the normal probability plot of residuals. One of the assumptions of the model is that the residuals have a normal distribution with an expected value of zero. Obviously that assumption does not hold and thus brings into question the validity of the results. Likewise the histogram in Figure 2 as well as the plot of residuals in Figures 3A and 4A indicate that the residuals corresponding to year 1967 are adversely affecting the regression, introducing a bias.

Investigating the data from the model year third-fourth quarter 1966, first-second quarter, 1967, it was found that 1966 was the only year in which there was a third quarter loss. It is obvious that the results of model year 1967 do not represent a normal situation. Since the regressions for quarterly fixed costs are so sensitive to third quarter results, the results of 1967 were not used and the regression was rerun using 1962-66, 1968-70 data.

Examination of the residuals from this regression shows that the assumptions of the regression model are now satisfied. The normal probability plot of residuals (Figure 1B) approximates a straight line passing through the origin. Plots of residuals versus the

independent variable (Figure 3B) and dependent variable (Figure 4B) show that the residuals now satisfy the requirement of randomness as well as homoscedasticity.

It should be noted that regressions were done using only five years of data (from 1965-66, 1968-70) but that the results obtained were inconclusive. The examination of residuals indicated a possible bias, but it was felt that since so few data points were used the indication of bias was not necessarily attributable to misspecification of the model. Thus this regression was ignored in favor of the revised regression using 1962-66, 1968-70 data. The data presented for fixed costs in Table 6 were determined using the revised regressions.

Finally, regression was used to derive the equation on page 21. Examination of the normal probability plot of residuals (Figure 5A) indicated that one data point was definitely out of line; this was also indicated by the histogram of residuals in Figure 6A. A plot of residuals versus the independent variable (revenue) in Figure 7A gives the same indication, suggesting introduction of a bias into the estimate.

As discussed in the text, we determined that the Corvette data did not correspond to the assumptions of the allocation procedure. Thus the regression was rerun excluding the Corvette data. Reexamination of the normal probability plot of residuals (Figure 5B) assures us that the assumptions of normality are now satisfied, as previously specified. In addition, the histogram of residuals (Figure 6B) and

the plots of residuals versus the independent variable (Figure 7B) and dependent variable (profits) in Figure 8 indicate that the requirements of randomness and homoscedasticity have been satisfied.

These investigations have confirmed that the regression model was used correctly. Although Durbin Watson statistics were not calculated, the random character of the plot of residuals appears sufficient to justify the assertion that autocorrelation is absent and that the estimates are the best, unbiased estimates obtainable. We are also satisfied that the decision to drop data points was valid and led to statistically correct results.

In a similar fashion, the regression of unit cost versus weight (pp. 20-21) was analyzed to determine its validity. We have already pointed out that the regression coefficients were found to be significant. The residuals were also examined and found to conform to the Gauss-Markov assumptions. Homoscedasticity was determined slightly differently than in the other regressions. The residuals were tested using the Glejser method and found to be homoscedastic.[1/] Thus the results of the statistical tests are assumed valid. Likewise, the normality of the residuals was established.

1/ "A New Test for Heteroscedasticity," Journal of the American Statistical Association, LXIV (1969), 16-32.

The regression of unit profit versus revenue, as shown on page 24, was similarly analyzed. The regression coefficients were found to be significantly greater than the .001 per cent level. The residuals conformed to the Gauss-Markov assumptions, including the normality assumption. The Glejser test showed the residuals were homoscedastic. Thus this regression is valid and the results can be used for the analysis shown in the text.

Analysis of Long-Term Fixed Costs

Normal Probability Plots of Residuals

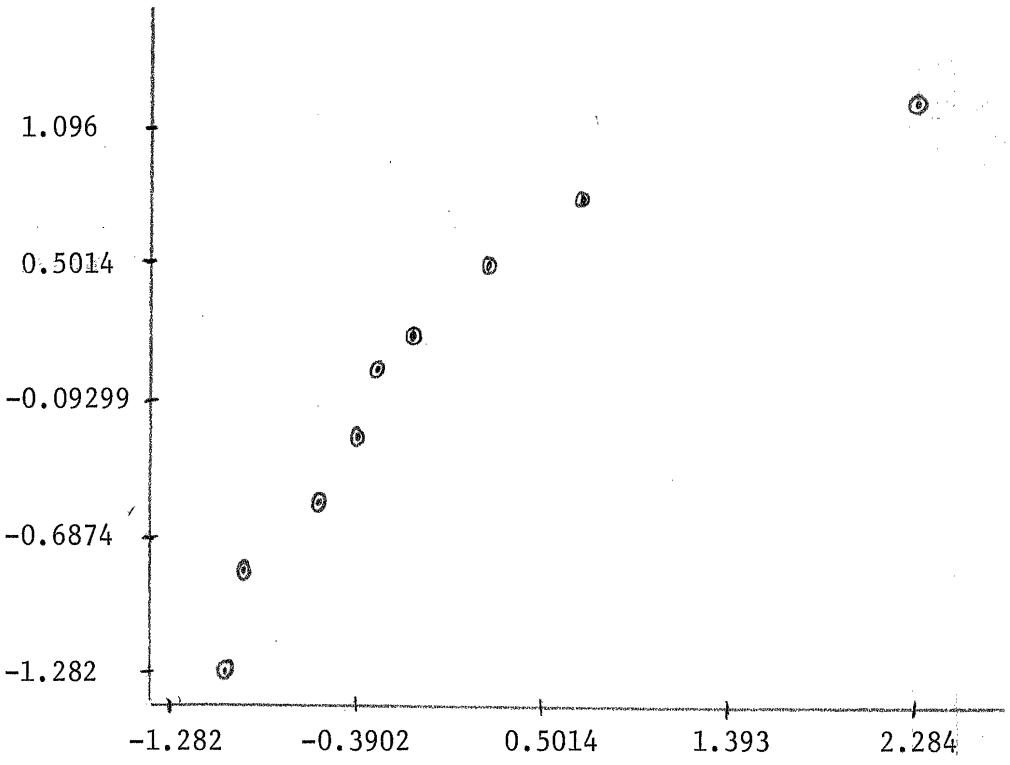


Fig. 1A. Regression using 1962-70 data.

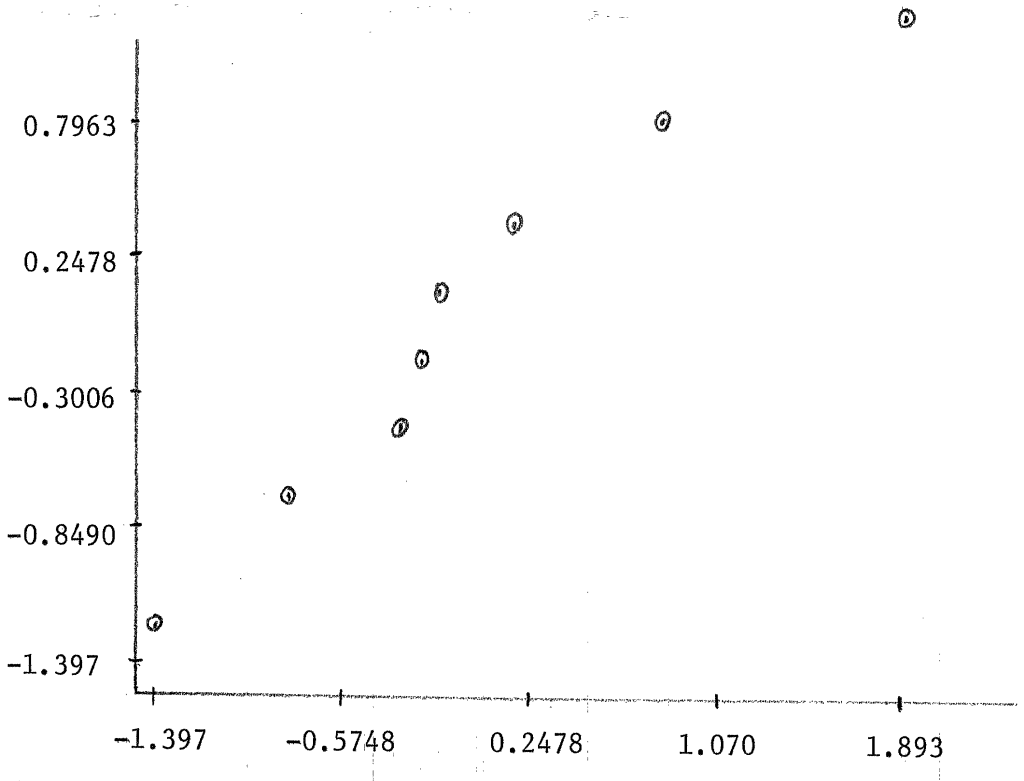


Fig. 1B. Regression using 1962-66, 1968-70 data.

Analysis of Long-Term Fixed Costs

Histogram of Residuals

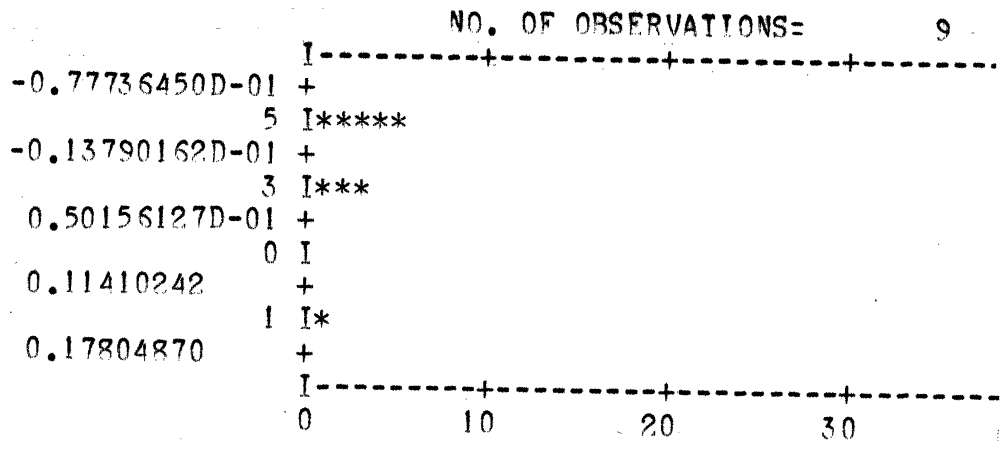


Fig. 2. Regression using 1962-70 data.

Analysis of Long-Term Fixed Costs

Plots of Residuals vs. Independent Variable

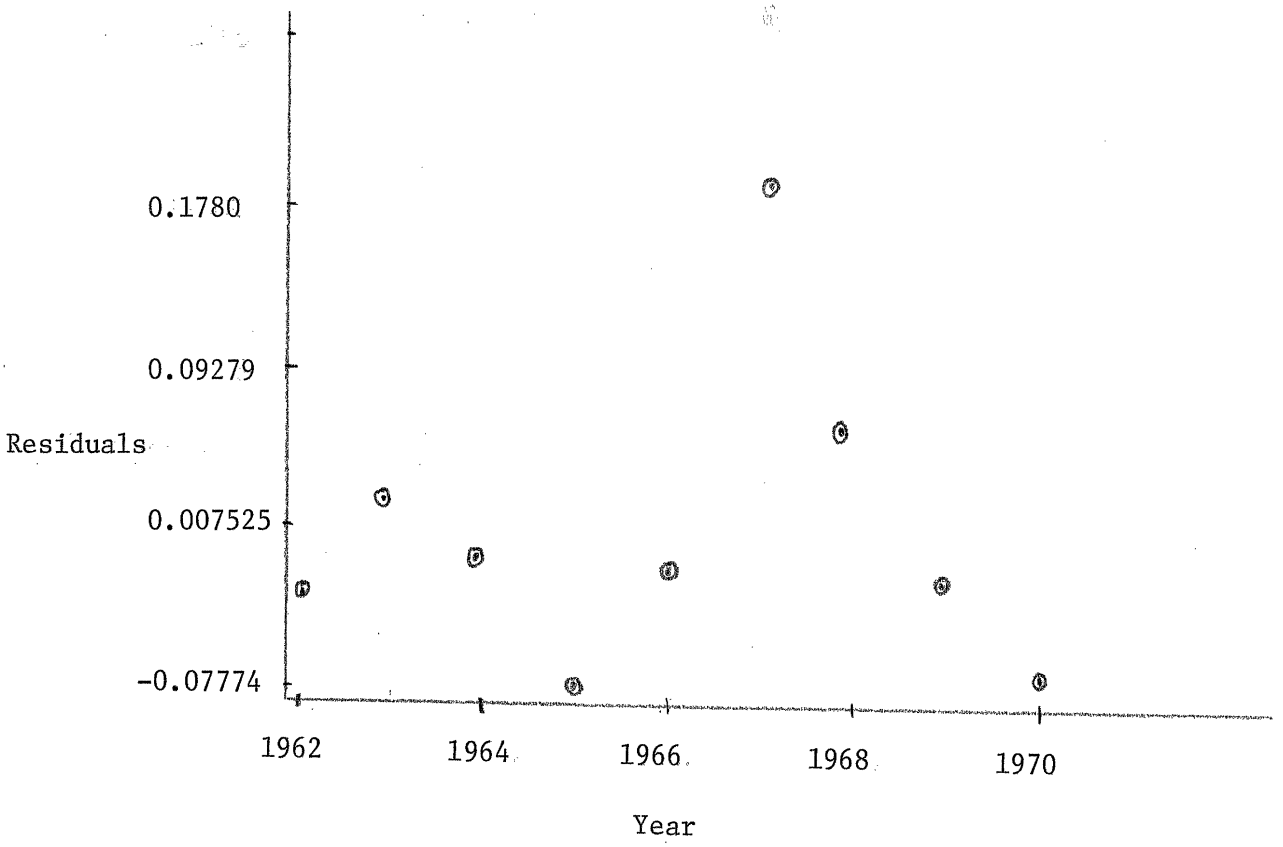


Fig. 3A. Regression using 1962-70 data.

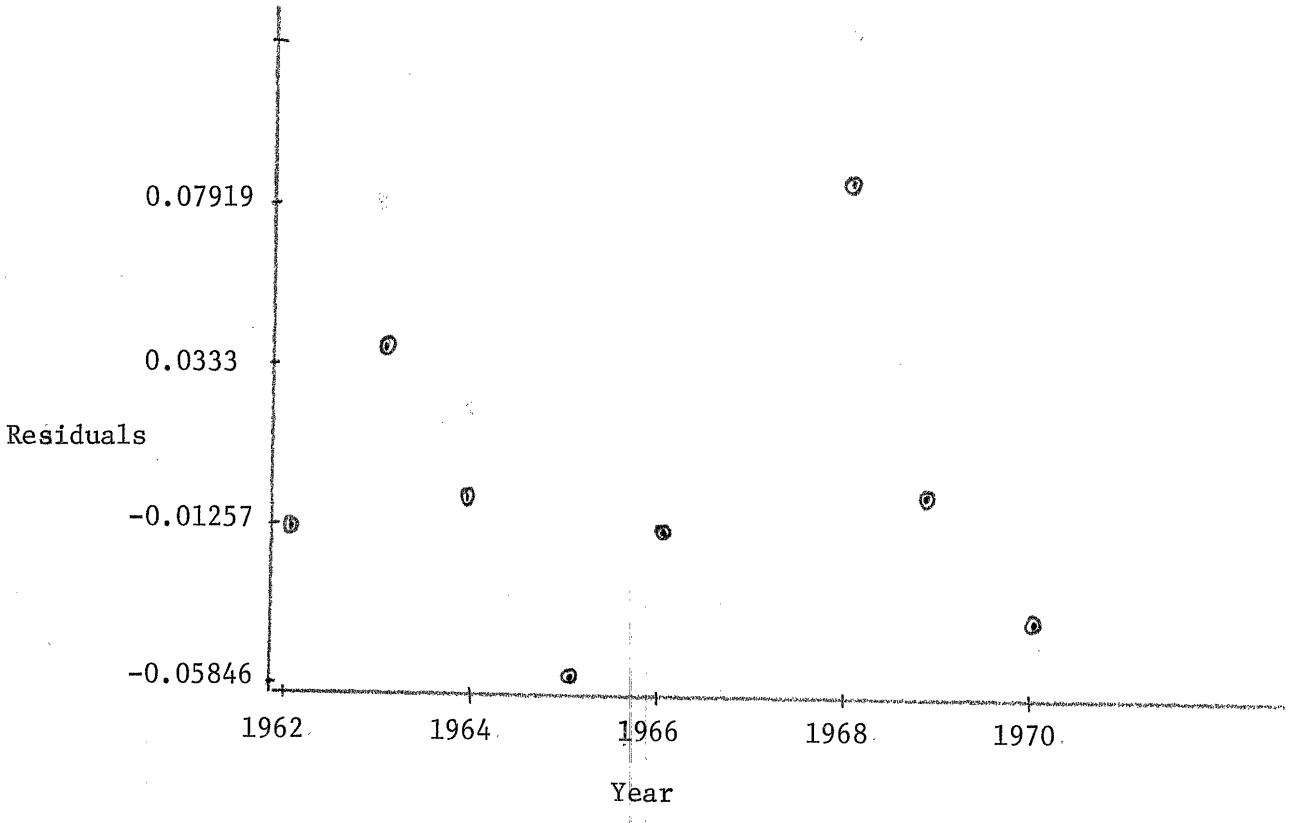


Fig. 3B. Regression using 1962-66, 1968-70 data.

Analysis of Long-Term Fixed Costs

Plots of Residuals vs. Dependent Variable

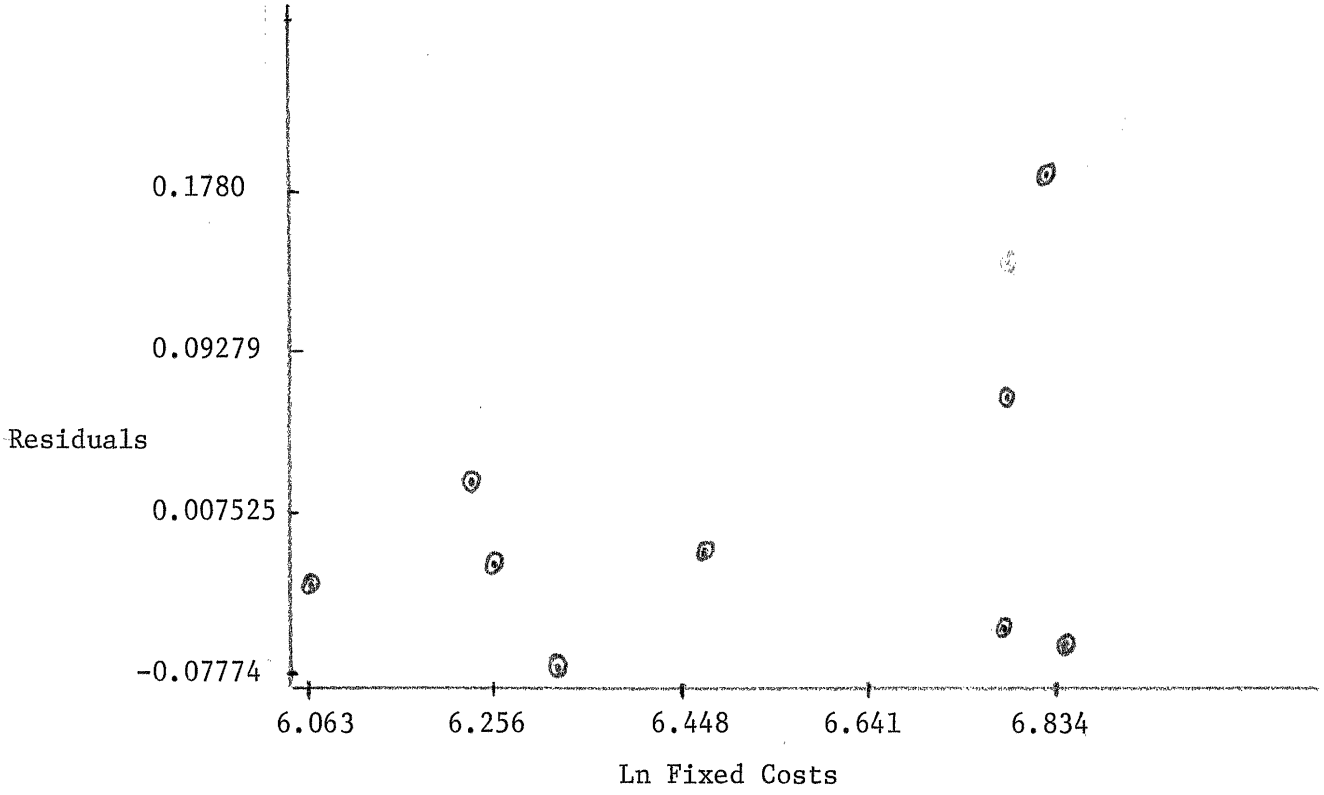


Fig. 4A. Regression using 1962-70 data.

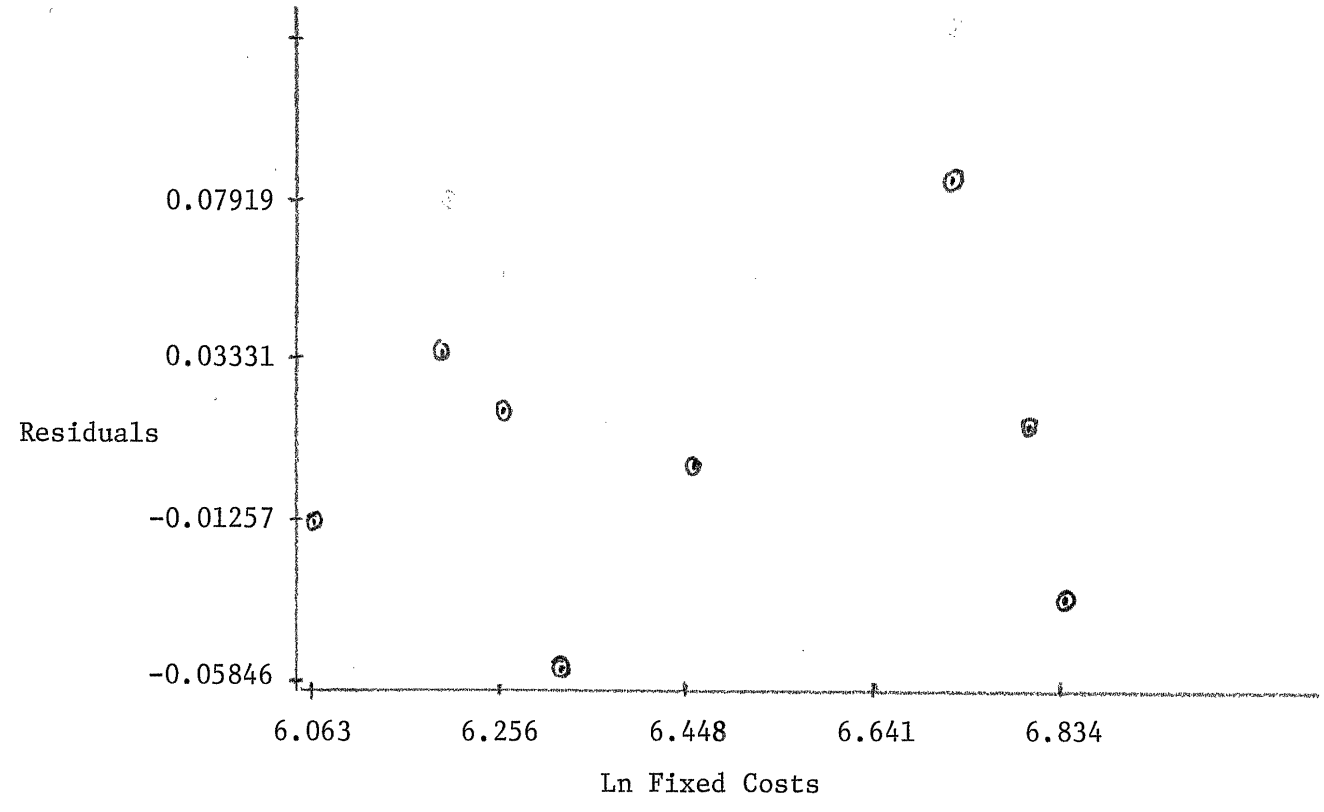


Fig. 4B. Regression using 1962-66, 1968-70 data.

Relationship between Revenue and Variable Profits

Plots of Residuals

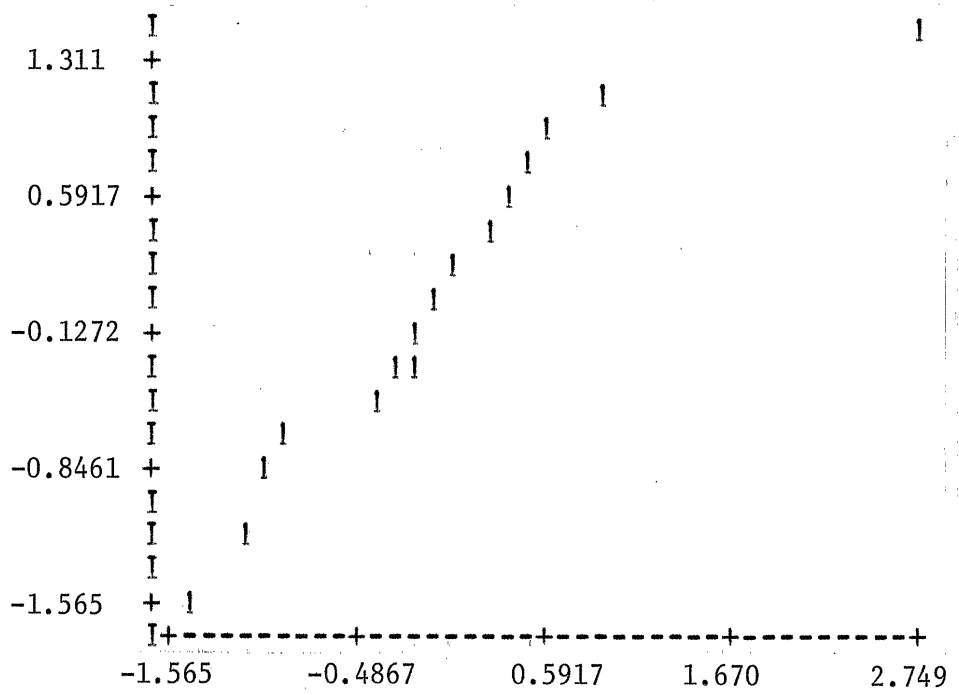


Fig. 5A. Regression with all data.

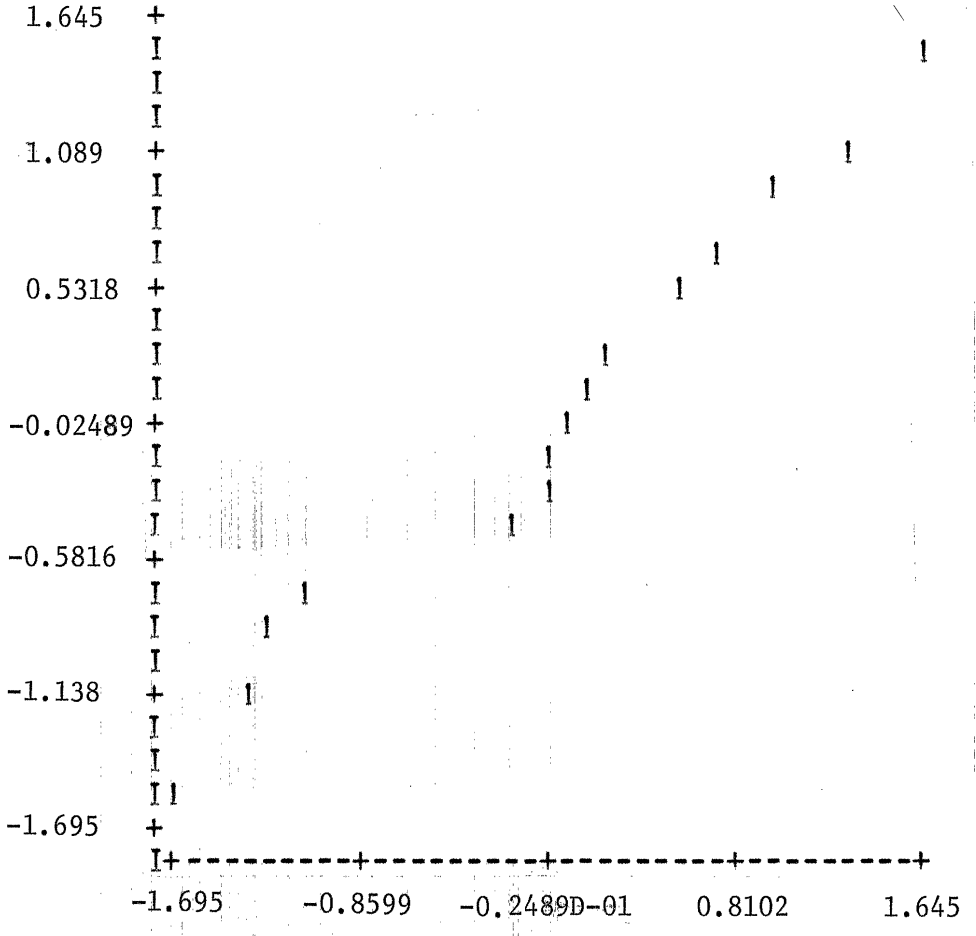


Fig. 5B. Regression excluding Corvette data.

Relationship between Revenue and Variable Profits

Histograms of Residuals

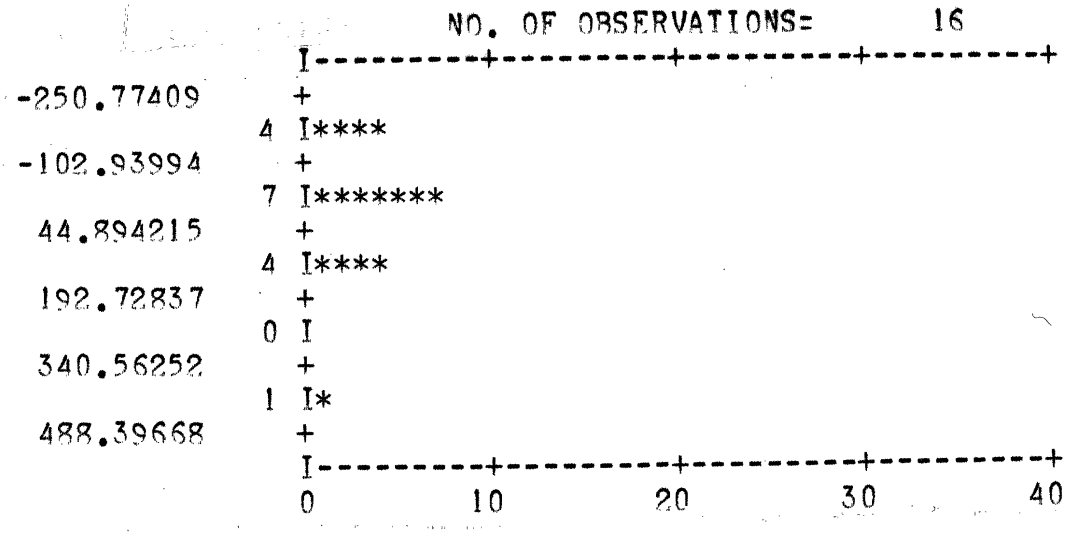


Fig. 6A. Regression with all data.

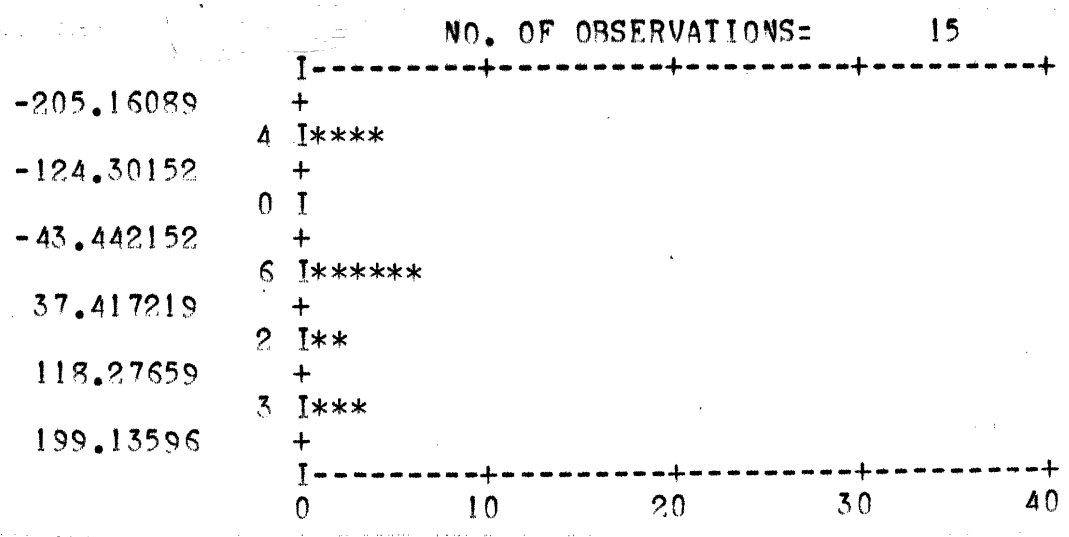


Fig. 6B. Regression excluding Corvette data.

Relationship between Sales and Variable Profits

Plots of Residuals vs. Independent Variable

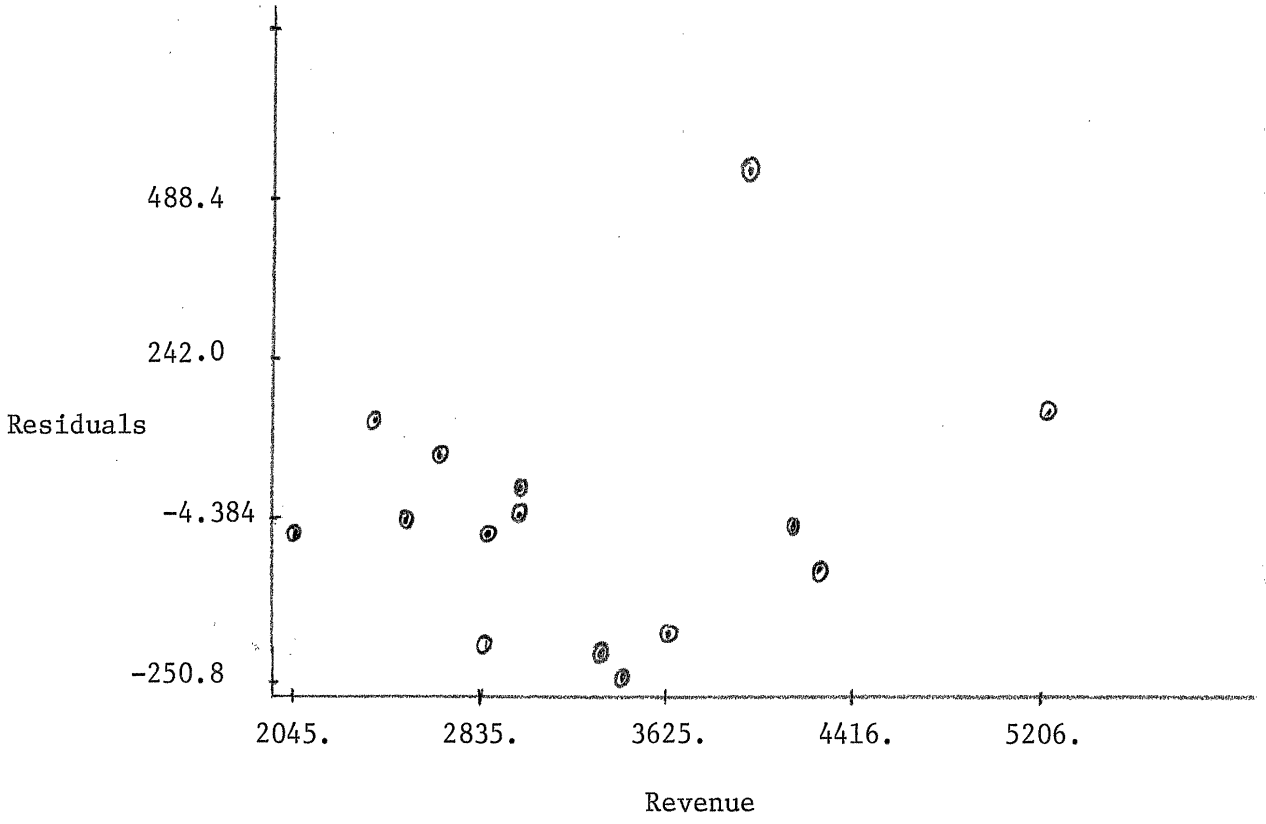


Fig. 7A. Regression with all data.

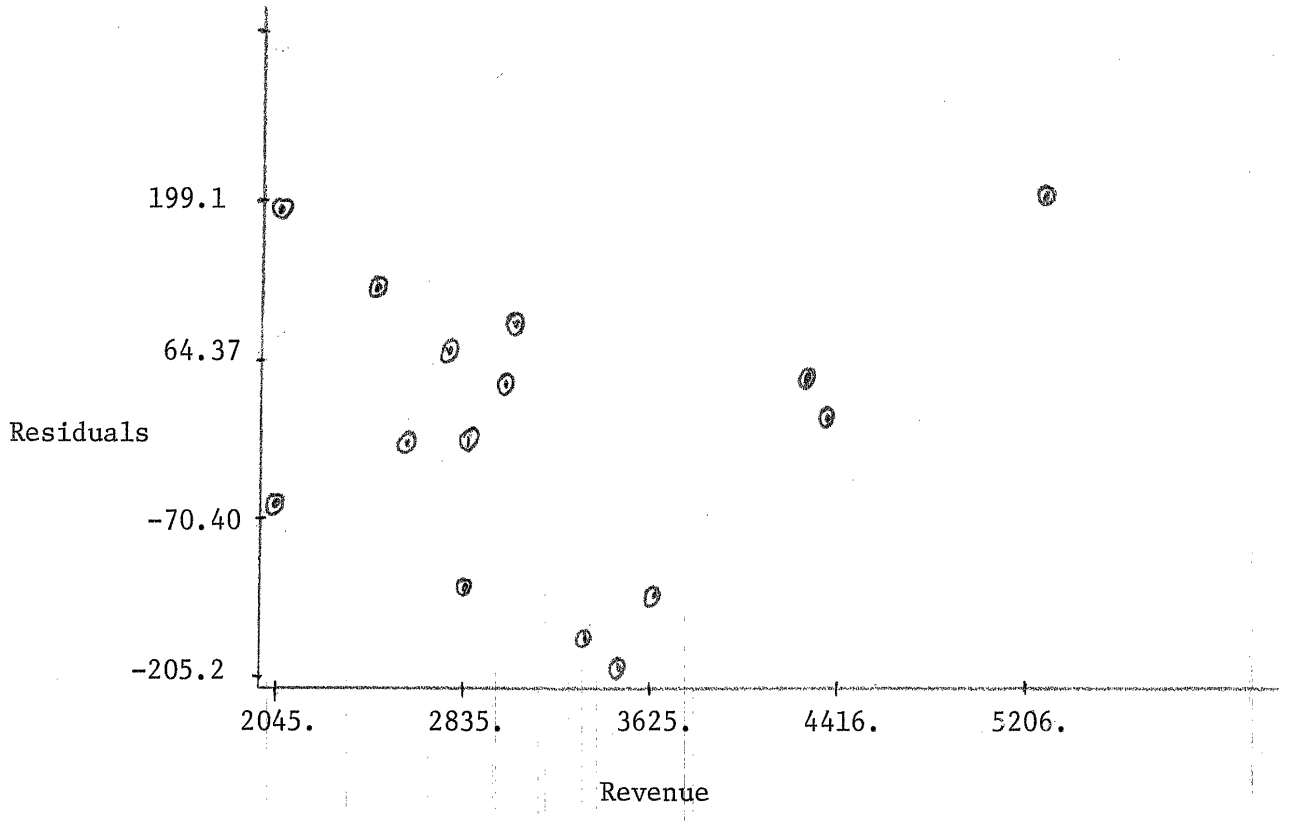


Fig. 7B. Regression excluding Corvette data.

Relationship between Sales and Variable Profits

Plots of Residuals vs. Dependent Variable

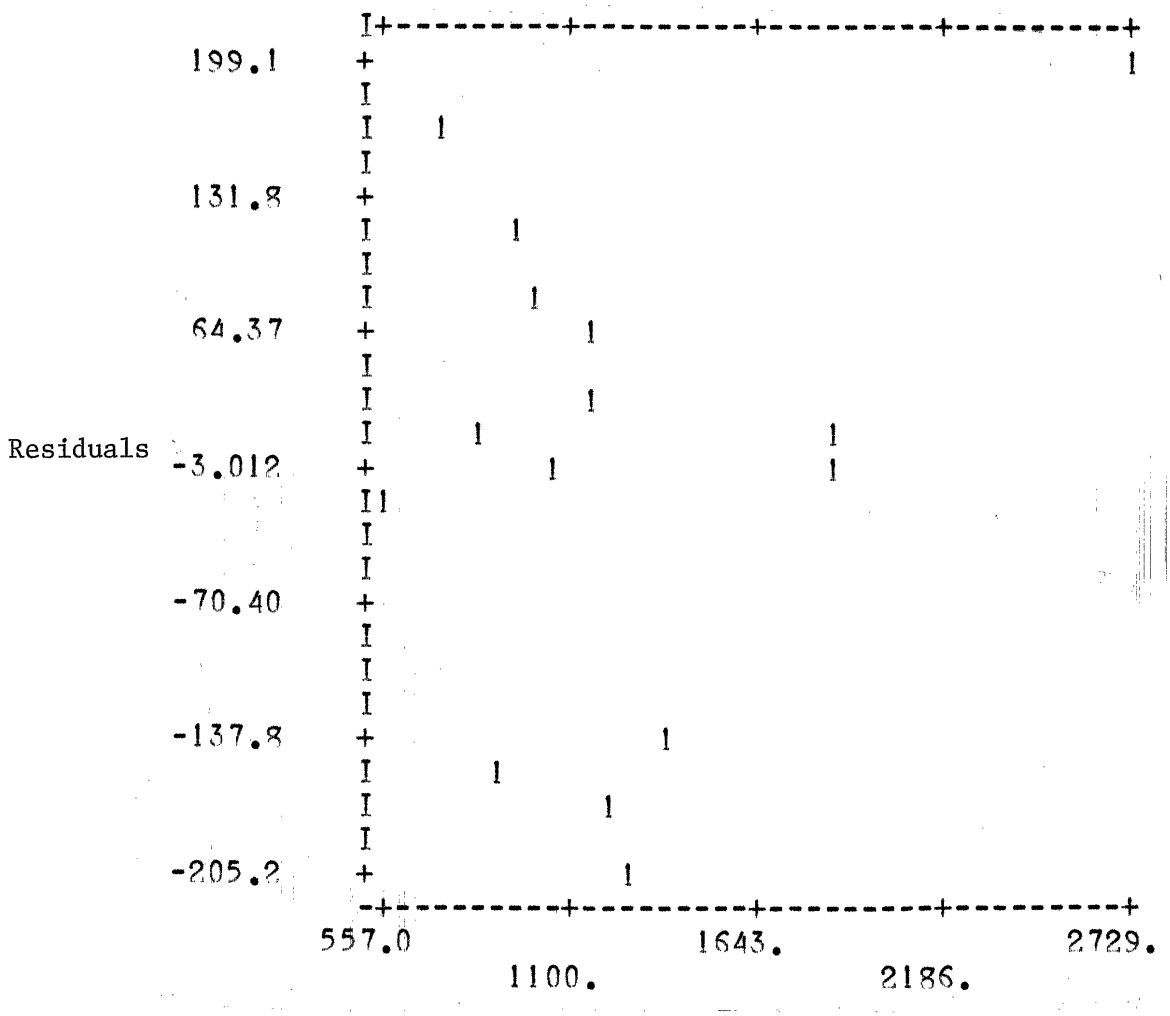


Fig. 8. Regression excluding Corvette data.