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An Analysis of SteelFab's Project Costs and Profits

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AN ANALYSIS OF STEELFAB'S PROJECT COSTS AND PROFITS

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Abstract

SteelFab is a structural steel fabricator with headquarters in Charlotte, North Carolina. In this study I analyze costs and profits for the firm. In particular, I estimate a cost function for SteelFab projects. I use the cost function to test the effects of project output, project regions and project type on costs. Short-run economies scale seem to exist. Costs increase as input prices increase, all else equal. Costs of new hospitals and specialty buildings are higher than new warehouses at a highly significant level. In light of the cost analysis, I analyzed profits with a focus on project size and project type. The evidence suggests that fabrication and erection of steel for large warehouses is consistently the most profitable type of SteelFab project.

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1. Introduction

SteelFab is an American Institute of Steel Construction (AISC) certified, fabricator of structural steel, headquartered in Charlotte, North Carolina. Steel fabrication does not involve the production of steel inside a steel mill that is most commonly associated with the steel industry. Steel fabricating is the process of preparing raw steel to building specifications. Steel fabricators saw, drill, and weld steel members to prepare them for instillation in the field. SteelFab has six production facilities spread out across the southeast and Texas. The NC location has the greatest production capability; employees at the facility can fabricate up to 4,000 tons per month. The remaining locations all range from 1,000-1,500 tons of steel per month. SteelFab competes with other steel fabricators for the contract to fabricate, deliver, and erect structural steel for various types of buildings. When a new building is being planned, general contractors send out invitations to bid to several steel fabricators. Most often the fabricator that submits the lowest bid, is awarded the contract for that job. Ultimately, the contract is awarded at the general contractor's discretion. The general contractor sets the time schedule for the project to be completed by the fabricator. Therefore, a fabricator's reputation and working relationship with general contractors could allow them to win a contract without being the lowest bid.

The bid-award nature of SteelFab's business makes cost minimization crucial. SteelFab wants to submit the lowest bid in order to win contracts. It can choose to compete in two ways. By providing the steel at lower costs than its competitors or by accepting a lower profit rate. It is likely that it uses a combination of the two, although, providing the steel at lower costs is clearly preferable. In economics, it is commonly assumed that firms are profit maximizing and make decisions to achieve the highest possible level of profit. Cost minimization is an important aspect of this assumption because a firm must be minimizing costs to maximize profit. The solution to the cost minimization problem is given in the form a cost function. A cost function minimizes costs for a given level of output. The cost function C (w_1, w_2, y) measures the minimal costs of producing y units of output when faced with factor prices (w_1, w_2) (Varian 2005).

The purpose of this research is to: measure the impact of input prices and output on project costs, test for differences in costs and profits across project regions and project types, and test for evidence of economies of scale for SteelFab projects. Combining the information from the cost function with profit analysis can aid in expansion strategy for the firm and resource management at the plant level.

2. Literature Review

In 2003, L. Pavlovcic et al. applied the concept of cost minimization to the optimization of steel frames. At the time, companies in the structural steel industry used volume minimization rather than cost minimization as their focus during steel frame design. Volume minimization means designing the steel frame with the lowest total volume of steel. Pavlovcic et al. recognized that fabrication and erection costs were only indirectly related to the volume of steel. To account for this, they used a very detailed cost function that included all essential fabrication costs, transportation, and erection costs. Pavlovcic et al. tested their cost function against a volume minimization function using a two-story steel structure as an example. Compared to the volume minimization function, total costs were only reduced by 0.7 percent and total volume was only 0.1 percent above the volume given by the volume minimization function. However, certain variables varied by as much as 11 percent. He believed these results were due in part to the size of his test example. In 65 percent of variables, cost contributions were directly related to the volume of the structure.

The cost function created by Pavlovcic et al. is a general form function that allows users to define their own parameters. Their research was not rooted in economic theory, they only wanted to account for every possible fabrication and erection cost. Their cost function was intended as a method to estimate and minimize steel construction costs before they occur to increase the efficiency of the construction market. SteelFab's business does not involve minimizing the costs of steel-frame design. Their goal is to minimize the costs of supplying and erecting the steel for the frame design that they are provided. This is done in accord with their primary goal of maximizing profits.

In 1991, Jha Raghbendra, et al. looked at the cost structure of India's iron and steel industry. The authors estimate a trans-log cost function to test for technical and allocative inefficiency in the Indian iron and steel industries. The cost function expanded on previous work done by Y. Toda et al. 1956, in which the authors estimate a Leontief cost function for Soviet manufacturing industries with two inputs, labor and capital. Jha Raghbendra et al. aggregate all input costs from the industry and include a variable that accounts for energy and material costs.

Raghbendra et al., find evidence of allocative efficiency in the Indian steel industry. The study provides evidence of significant economies of scale. They also find technical change over time to be biased toward the use of labor, energy, and materials and the saving of capital. It is interesting that inputs were being allocated efficiently within the firm because the iron and steel industries in India were largely public and not operating in a perfectly competitive market. I expect to find that SteelFab will display similar evidence of economies of scale and assume that they are also using inputs in an efficient manner.

Like Jha Raghbendra et al., I account for material and energy costs and check for economies of scale. However, the cost function I estimate is different from the cost functions estimated in previous literature. Previous cost functions were generalized to the steel industry at large. Raghbendra et al., studied the iron and steel manufacturing industry. This study focuses on a single firm that is a fabricator of manufactured steel. My cost function is estimated with cost information from SteelFab and should be used to evaluate the fabricating process for SteelFab alone.

3. Data Sources and Variables

In this study, I used data from SteelFab on completed projects and the corresponding final estimates for each project to estimate a Cobb-Douglas cost function. The purpose of estimating this cost function is to measure the relationship of several independent variables and costs. The properties of the Cobb-Douglas cost function provide for easy interpretations of coefficients and allow me to evaluate the degree to which SteelFab faces scale economies.

The jobs used in this study were all completed in 2017 and 2018. A job is considered completed when the accounting for the project occurs. The estimates for completed jobs ranged from 2014 to 2018. All reported costs and prices are reported in December 31, 2018 dollars which were converted using an implicit GDP price deflator. The implicit GDP price deflator was obtained from the Bureau of Economic Analysis. I chose to use the GDP price deflator over a CPI index adjustment because the GDP price deflator excludes imports, making it the more relevant measure of price changes for SteelFab, who operates entirely within the U.S.

Once SteelFab has decided to bid a project, the structural drawings are sent to an estimator. The estimator uses a program called Fabtrol to input all the structural steel and connection materials for the project. The estimators are also expected to account for all the additional labor that will be required to fabricate each piece of steel such as welds and fit-up time. Fabtrol then provides a report breaking down the estimated amount of structural steel, costs of structural steel, number of labor hours, and cost of labor. The estimated amount of structural steel should be very close to the actual amount steel used in the project. The estimated labor is not an exact science, each estimator uses different methods to account for labor and ultimately the labor hours and costs are subject to review and often changed by managers. In addition to estimating structural steel costs, the estimators are in constant contact with subcontractors that provide steel joist, steel deck, miscellaneous metal, and the erection of structural steel. Quotes from these vendors are taken and combined with the reports from Fabtrol to generate a final estimate. Some level of profit is added to the estimate and submitted as a bid to the contractor.

All the data for the independent variables were obtained from the final estimates for each project. For 87 of the 143 projects the final estimate number used in the bid perfectly matched the original contract price for the completed jobs. Of the 56 projects whose final estimate number did not perfectly match the original contract price, 38 varied by less than 3 percent and 18 varied by 3-10 percent. The variance likely results from contract negotiations or job changes that occurred before the original contract was made. A dummy variable is included for projects where the final estimate number differed from the original contract price by 3 percent or greater.

The large number of projects in which the final estimate number matched the original contract prices suggests that the contract prices were not adjusted for changes in inflation between the time of the estimate and formation of the contract. It is also possible that SteelFab is forward looking in their estimates and has accounted for this themselves. To avoid over adjusting, I did not adjust the prices and wages from the estimates to 2018 dollars based on the date of the estimate. For jobs completed in 2017, I adjusted the prices and wages from the estimates to December 31, 2018 dollars from December 31, 2017. This was done to put all prices and costs into comparable dollar units. For jobs completed in 2018, I did not adjust the prices and wages of the estimates for inflation.

The dependent variable in my regression is final project costs which is the final total cost SteelFab reported for the project. The final project cost includes actual explicit cost and overhead costs for each project. The final project costs include costs of change orders. The final project costs were pulled from Work-In-Progress sheets for the years

2017 and 2018. The costs reported on the 2018 sheet were reported as of December 31, 2018. The costs on the 2017 sheet were reported as of December 31, 2017 and were adjusted to December 31, 2018 dollars.

Total tons of steel is the total tonnage of structural steel, steel joist, and steel deck estimated for each project. It is used as a measure of output for each project. The number for structural steel tons is reported directly from Fabtrol. The steel joist and steel deck numbers are from quotes provided by joist and deck vendors. Steel joist is quoted in tons, but steel deck is quoted in the number of deck squares. I converted the number of deck squares into tons using data from Canam, a national steel deck supplier. Type B 20-gauge roof deck is used as the standard of conversion because it is one of the most commonly used types of deck square. In reality, each project will differ in the exact type of deck square used. Each deck square is 10x10 feet or 100 square feet with a weight of 1.9 pounds per square foot ("Steel Deck" 2010). The conversion to tons is ((100*1.9)*Number of Deck Squares)/2000. After calculating the total tons of steel, the total is adjusted using a multiplier to account for change orders.

Many projects include miscellaneous metals that are supplied by a subcontractor. They are a part of the final output for which there is no solid quantity measure. Misc. metals include items such as steel ladders and steel handrails. The only measure of misc. metals is the total dollar amount quoted by the subcontractor. This amount was used as a measure of the costs of miscellaneous metal per project. An issue of including misc. metal cost in my regression is that roughly a quarter of the projects included no misc. metals at all. Thus, the dollar amount for that project is zero. This prevented me from being able to take the natural log of the variable and forced me to include the unlogged version. This affects the interpretation of the misc. metals costs variable and deviates from the Cobb-Douglas model I estimate.

The variable erection price is a measure of the erection cost per ton for each project. The price is calculated by taking the total dollar amount for erection costs and dividing it by total tons (unadjusted for change orders). It reflects the price SteelFab pays to have the steel erected for each project. Four projects were furnish only, meaning SteelFab only supplies the fabricated steel and does not erect it. For these projects I entered an erection cost of 0.001 so that I could still take the natural log of the price.

Price of steel inputs is the weighted mean cost per ton of structural steel, steel joist, and steel deck for each project. The final estimate reports a final dollar cost for structural steel, steel joist, and steel deck. The total cost of structural steel is reported directly from the Fabtrol report. The steel joist and deck costs are taken from quotes provided by subcontractors. These numbers were summed and divided by total tons (unadjusted for change orders) to provide a measure for the price of steel inputs.

Wage is the average price of labor per hour for each project. The wage includes direct labor costs and all overhead costs associated with labor. There are two components of the wage, structural labor costs and project management costs. The final estimate reports the estimated number of structural labor hours, project manager hours, total structural labor costs, and project manager costs. The wage represents (total structural labor costs + project manager costs) / (structural labor hours + project manager hours). In several cases, the final estimate omitted project manager hours. In these cases, to back out project manager hours the estimated PM costs were divided by 60. This is the standard wage used by SteelFab to estimate the cost of a project manager hour.

Freight price is the dollars per ton of steel that it is expected to cost to ship the steel to the project's location. SteelFab uses a formula to calculate freight costs based on the distance and size of the project. I took this dollar amount and divided it by tons of structural steel. All prices and wages are reported in December 31, 2018 dollars, converted using the implicit GDP price deflator.

Change orders are very prevalent in the construction industry and 80 percent of the completed projects in my study included change orders. In projects that included change orders, they made up an average of 8.38 percent of the final billing price. This presented a problem because the only data available for change orders was the dollar amount of the change order. For each project, the final billing price is equal to the original contract plus any change orders. To account for the change orders, I multiplied the total tons of steel by Final Billing Price / Original Contract. This assumed the change order increased the amount steel in equal proportion to the original contract. I included a changer order dummy to check the impact of change orders on project costs.

Initial analysis of residuals showed no signs of heteroskedasticity, but the white test was close to being statistically significant. The possibility of non-linear heteroskedasticity in the model led me to report robust standard errors for the variables.

Data Description

The data in this study were taken from 143 completed projects and their estimates. The company handles a wide range of projects. Final costs range from $11,774.99 to

$25,094,642. However, the middle 90 percent of their final project costs are between $37,070.02 and $7,047,602. The total tonnage also varies quite a bit, the smallest project included only .44 tons of steel while the largest was over 10,000 tons. The average size of all projects is 703.58 total tons of steel.

The price of steel inputs ranged from $768.90 to $1,915.54. This price range is slightly above the average industry range of $770-$1160 per ton for WF structural steel in 2017 because I combined structural steel, steel joist, and steel deck into one price (Barg, Steve, et al. 2018). The average wage across projects is $54.58 with a range from $43.84- $58.83. Freight price had a good bit of variability, with a price range of $28-$1,940. Misc. metal costs range from $0-$1,544,614. The mean erection price for projects is $2,046.81.

SteelFab handles projects for new buildings as well as the renovation and expansion of current buildings. Nearly 30 percent of the projects in this study were building renovations or expansions. The variable renovate is a dummy variable that accounts for whether the project is for a new building or an addition to existing buildings. In addition to testing for the effect of renovations alone, I interact the variable with building types for each project. This allows me to compare the impact of renovation projects for each building type. Table 3.1 shows the descriptive statistics for final project costs, tons of steel, price of steel inputs, wage, freight price, erection price, misc. metal cost, change orders, and the bid versus original contract dummy.

The variable region is a categorical dummy that was included to test for regional effects on project costs. Mid-Atlantic includes projects completed in MD, DC, and VA.

North includes projects completed in NY, NJ, PA, and OH. West includes projects in UT, CO, AZ, and OK. South includes AL, TN, NC, SC, GA, and FL. The majority of SteelFab's jobs are completed in the South, which accounted for 76.22 percent of the projects. South was used as the base category in the regression.

Building type was recorded for each project to test for differences across buildings. The buildings were separated into four categories: hospitals, offices, other, and warehouses. The category other represents projects that did not fit well into the other three categories and were not prevalent enough to warrant their own category. This category includes: museums, gyms, parking decks, hotels, schools, YMCA buildings, malls, sports stadiums, and specialty manufacturing plants. Warehouses were the most common building type, accounting for 38.46 percent of the projects in the study. They were used as the base in the regression. The descriptive statistics for project region and building type can be seen in Table 3.2.

4. Model

I estimate a Cobb-Douglas cost function for SteelFab projects. Theory gives us the Cobb-Douglas model that estimates costs as a function of quantity and input prices:

$$C\ (q_i, \mathbf{p}_i\ ) = Ap1^{\beta_1}\, p2^{\beta_2} p3^{\beta_3}\, p4^{\beta_4} q^{\gamma} \qquad (1)$$

In which q_i is the total estimated tonnage of the *i*-th project, $p1_i$ is the price of steel inputs for the *i*-th project, $p2_i$ is the average price of labor for the *i*-th project, $p3_i$ is the price of freight for the *i*-th project, $p4_i$ is the price of erection for the *i*-th project, and the technology parameter A represents:

$$A = \exp(\alpha_1 + \alpha_2 DifBidCon + \alpha_3 ChangeOrder + \alpha_4 OtherRen + \alpha_5 OfficeRen + \alpha_6 HospRen + \alpha_7 Renovate + \alpha_8 Other + \alpha_9 Office + \alpha_{10} Hospital + \alpha_{11} West + \alpha_{12} North + \alpha_{13} MidAtlantic + \alpha_{14} MiscCost) \quad (2)$$

Combining equations 1 and 2 and adding in the error term gives us the equation:

$$C(q_i, p_i) = \exp(\alpha_1 + \alpha_2 DifBidCon + \alpha_3 ChangeOrder + \alpha_4 OtherRen + \alpha_5 OfficeRen + \alpha_6 HospRen + \alpha_7 Renovate + \alpha_8 Other + \alpha_9 Office + \alpha_{10} Hospital + \alpha_{11} West + \alpha_{12} North + \alpha_{13} MidAtlantic + \alpha_{14} MiscCost)\ p1_i^{\beta_1}\ p2_i^{\beta_2} p3_i^{\beta_3}\ p4_i^{\beta_4} q_i^{\gamma} e_i^{\varepsilon} \quad (3)$$

Taking the natural log of both side we obtain the model that I estimated in Stata:

$$\ln C = \alpha_1 + \alpha_2 DifBidCon + \alpha_3 ChangeOrder + \alpha_4 OtherRen + \alpha_5 OfficeRen + \alpha_6 HospRen + \alpha_7 Renovate + \alpha_8 Other + \alpha_9 Office + \alpha_{10} Hospital + \alpha_{11} West + \alpha_{12} North + \alpha_{13} MidAtlantic + \alpha_{14} MiscCost + \beta_1 \ln p1_i + \beta_2 \ln p2_i + \beta_3 \ln p3_i + \beta_4 \ln p4_i + \gamma \ln q_i + \varepsilon \quad (4)$$

Dummy variables are interpreted using the formula e^ (estimated coefficient) – 1.

5. Results

The results of the estimated model can be seen in Table 5.1. The model shows that costs increase as output and input prices increase. All price variable coefficients were positive.

A 1 percent increase in total tons of steel is expected to increase total cost by .773 percent and is significant at the 1 percent level. The coefficient for price of steel inputs and wage were not significant. The coefficient on freight price is .238 and is significant at the 5 percent level. A 1 percent increase in erection price is expected to increase final costs by .055 percent and is significant at the 1 percent level. The coefficient for misc. metal price was .0058 and was significant at the 1 percent level. This means a 10,000 dollar increase in the price of misc. metal is expected to increase total costs by approximately .58 percent.

Regional Effects

The coefficients on the North and MidAtlantic regions are positive, but not significant. Suggesting that there is no statistical difference in projects costs completed in the North, MidAtlantic, and South. The coefficient on the West region is negative and also statistically insignificant.

Building Type and Renovations

The coefficients on building type are all relative to the base building, new warehouses. The coefficients on new hospitals and new “other” projects are both significant at the 1 percent level. New hospitals are expected to cost 73.5 percent more than new warehouses and “other” buildings are expected cost 32.8 percent more than warehouses, all else equal. Costs for new office buildings do not statistically differ from new warehouses.

The variable Renovation represents the effect of warehouse renovations and expansions relative to new warehouses. The coefficient on Renovation is positive, but highly insignificant suggesting that costs for the two types of project do not differ. The variables HospRen, OfficeRen, and OtherRen are all insignificant, further supporting the evidence that costs do not differ between new buildings and renovations.

Change Orders and Estimate Differences

The coefficient on the change order dummy is large and significant at the 1 percent level. The results suggest that projects with change orders are 40.8 percent more costly on average.

The coefficient on the dummy variable DifBidCon is .173 and is significant at the 10 percent level. The projects in which the final estimate number differed from the original contract price are expected to cost 18.94 percent more, all else equal.

6. Discussion

Prices

The results of my cost function are largely in line with economic theory. Project costs increase as quantity and input prices increase. Cost functions assume homogeneity of degree one for price variables. The coefficients, if everything has been accounted for, should sum to 1. The sum of the coefficients on the four price variables in the model is 0.976.

The statistical insignificance of the coefficient on the price of steel inputs is surprising. Changes in the price of steel should have a significant impact on project costs. The results could be due to the way the variable was calculated. Steel price included the price of steel joist and deck. However, the joist and deck prices were taken from quotes provided by subcontractors. SteelFab is not obligated to use the subcontractors that provided the quote and if they find a cheaper quote after winning the job then that is who they will use for joist and deck. This would make the price of steel reported in the estimate inaccurate.

The coefficient on the wage variable was statistically insignificant. The wage variable was created from estimates that have potential for human error in the estimation of labor. The number of labor hours and cost of labor reported by Fabtrol are often adjusted based on previous experiences. Additionally, the number of project manager hours for each project is decided by the estimator. The number is based entirely off intuition and past experience. Furthermore, the wage rate used by the estimators is scaled to cover all overhead costs associated with the labor. It is possible that measurement error could be contributing to the statistical insignificance of the coefficient on wage in the model. Further research should be done to estimate the impact of measurement error in the wage variable and to explore the use of other models such as CES or trans-log cost functions.

Output

The coefficient on output is less than one. SteelFab appears to enjoy a form of economies of scale. The average variable costs are falling as output increases. However, it is not textbook example of economies of scale that includes long-run cost. Specific to SteelFab and each individual project, costs rise at a slower rate than output. This is evidence of short-run variable economies of scale. The coefficient on output is extremely close to the elasticity of 0.798 that Jha Raghbendra et al. reported for producers of steel in India in 1991. Consequently, larger projects might be more profitable, up to the point that these short-run economies of scale hold.

Project Region

The statistical insignificance of the effect of a project's region came as a surprise. Five out of six fabrication plants are in the Southeast and the company is headquartered in Charlotte, NC. I expected to find projects completed in the south to be less costly on average, due to their long working relationship with the subcontractors in the area. This does not appear to be the case. The model shows no difference in project costs across regions, holding all else constant. The input variables in the model could be picking up any sources of cost difference between project regions.

Given the results of the cost function I did surface level analysis of the data. The average final cost per ton of steel was 31.80 percent greater for jobs in the south than for all other regions. However, the average project size in all other regions was 126.12 percent larger than the average project size in the south. This suggests that SteelFab may enjoy an advantage of variable economies of scale over its competitors in other regions. Thus, allowing them to be competitive for larger projects despite greater shipping costs.

Project Type

The positive and significant results for building types were puzzling. New warehouses are the base in my regression because warehouses are a "cookie cutter" type of project. While they can vary greatly in size, they are generally the simplest type of building to fabricate and erect. They are also the most common project type. New "other" buildings and hospitals are both significantly more costly, all else equal, than new warehouses. Hospitals and "other" buildings are likely to have greater fabrication and erection costs. However, these costs are accounted for in the model. The coefficients on building type could represent the impact from more complicated projects on all un-accounted for costs.

The variables for building type could also be picking up the effects of varying levels of overhead amongst project types. The labor rate applied to an hour of labor includes all overhead costs. Accountants in the firm take data on all overhead costs and average these costs across labor hours to calculate the appropriate labor rate. For example, in 2018 the accountants might find the average labor hour including overhead ran $55 an hour. This rate is then the standard used by estimators to account for the costs of labor. However, I think it is likely that all labor hours are not created equal. A labor hour for the fabrication of a warehouse could run $50 an hour and a labor hour for the fabrication of a hospital could run $60. If the labor rate is applied to each project regardless of building type then the variables could be picking up the variance in overhead costs across projects.

I expected renovations and expansion to be more costly on average than new projects. However, both models show there is no statistical difference between a new project and a renovation/expansion.

Change Orders

There are two plausible reasons why change orders have such a large effect on project costs. The first is the change order dummy measures transaction costs that aren't accounted for in the model. Consider two projects, one with final output of 1,000 tons without change orders and one with an output of 900 tons initially and an additional 100 tons of change orders. The final output for each project is ultimately the same, and for our purposes we assume price of steel remains the same as well. However, the entire production process must be restarted for the new 100 tons starting back with new estimates for the changes. Thus, the second project can almost be considered two different projects. The cost function assumes that inputs are used in one fixed combination for a given level of output. When the final output includes change orders this input combination is different than the one predicted by the model. The model does not allow for qualitative differences in input use. The change order dummy could be picking up the transaction costs of restarting the production process that are not accounted for in the model.

Another possible reason for the size of this coefficient is that it could be picking up some of the errors from missing data. Without data for the composition of the change orders I was unable to use updated prices or measures of quantity. The multiplier applied to the output variable roughly accounts for the expected increase in output, but prices are assumed to remain the same. The multiplier likely overstates the amount of steel inside the change order. Most change orders are for smaller more intricate pieces of steel. It is not usual to add on new large columns or beams mid project. However, these types of steel members account for much of the tonnage measured in the initial estimate. Also, the smaller more intricate pieces of steel are likely to cost more and have higher erection prices. The assumption that prices inside the change order remain the same is unrealistic and the prices are likely understated. Important further research would include the actual data from change orders in the regression.

The coefficient on the variable DifBidCon suggests that projects in which the final estimate number differed from the original contract price by greater than 3 percent were 18.94 percent more costly, all else equal. This means that for these projects, something was likely added to the project that I did not measure in the model. Including data on the sources of the price differences would likely take away the effects of this variable.

Profit Analysis

In order to supplement some of the analysis and conclusions drawn from my cost function, I performed some simple profit analysis of SteelFab projects. SteelFab builds in 10 percent profit margin to their estimate templates. The profit margin is adjusted from the standard 10 percent on a project by project basis. I looked at the profit margin, ((final billing price – total final cost) / final billing price) *100, for the smallest 25 percent, middle 50 percent, and largest 25 percent of jobs. The results can be seen in Figure 6.1. The graph shows a clear negative relationship between profit margin percent and project size. As project size increase, the net profit margin decreases. Although, the variance of the profit margin is also largest for the smallest 25 percent of projects. This relationship exists for several reasons. With really small projects the denominator is sufficiently small that extremely modest profits can create large net profit margin percentages. Also, it must be worth their while for SteelFab to take on the project at all. It is not rational for SteelFab to risk incurring a loss or to take time away from other ventures for 10% profit on a $20,000 project. Therefore, when bidding very small projects they often mark-up the price by 20-30 percent. This is a textbook example of a firm being compensated for additional risk. In addition to marking up small projects, SteelFab will often shave points off their final profit margin on extremely large projects. These types of projects have potential to bring in very large dollar amounts of profit. In order to make their final bid more competitive, they adjust the profit margin down to say 8 percent. Driving down the average profit margin for the largest projects.

The presence of what I call short-run variable economies of scale led me to investigate the relationship between project size and profitability. The results can be seen in Figure 6.2. The relationship between profit and project size is inverse that of project size and profit margin. As expected, larger projects bring larger amounts of profit. There are still several interesting takeaways from this graph. First, except for one outlier in the middle 50 percent of projects, none of them ever break the $400,000 amount for profits. In comparison, the upper 25 percent of projects have six projects that reported over $800,000 in profits. Additionally, the upper 25 percent of projects only report 2 jobs in the red. The same as the middle 50 percent of projects. Despite the much lower profit margins, SteelFab profits most from its largest 25 percent of projects.

In my cost analysis of SteelFab projects I found that new hospitals and "other" buildings were more costly on average than new warehouses. It is also relevant to breakdown each project type by its profitability. I looked at the profit margins for each type of building. The results are shown in Figure 6.3. Despite being 73.5 percent more costly than warehouses on average, all hospitals had positive profit margins. Their average profit margin was 15.6 percent. This is evidence that SteelFab is accurately estimating and accounting for these higher costs in their bids. Several "other" projects were reported at a loss and they have the lowest mean profit margin of 11.23. This likely stems from the uniqueness of the projects, making them more difficult to estimate, fabricate, and erect. Warehouses have the next lowest mean profit margin at 11.93 percent. However, the variance of warehouse profit margins is 36.22 compared to 94.37 for "other" buildings. Consistency is important to consider when evaluating the profitability of various projects and warehouses provide by far the most consistent profit margins.

Figure 6.4 shows the breakdown of dollar profits by building type. Warehouses report the highest mean profits of $263,261 followed by Hospitals with a mean of $225,545. Outside of two outliers, hospitals never break $400,000 in profits. Office buildings, with an average profit of $84,718, don't break $400,000 at all. "Other" jobs are interesting, due to the wide variety of project types included in this category. They report profits as low -$100,000 and as high as $1,287,632. I investigated the type of "other" projects responsible for the smallest and largest profits and found no real trend in the type of buildings. Instead I found that the jobs with the four largest original contracts were the jobs with the top three highest profits and the -$100,000 loss. This evidence supports the idea that while larger projects often have an upside of potentially larger profits, inaccurate estimates or mismanagement can result in larger losses. Therefore, when dealing with large projects within the "other" category, extra measures should be taken to mitigate these risks. Such as built-in profit contingencies.

7. Conclusions

The cost-function I estimate in this paper provides important insights to some of the business decisions facing SteelFab managers. The model shows that all else equal, costs rise at a slower rate than output. Freight price has a substantial and significant effect on costs. This is an important factor when considering locations for new fabrication plants.

The profit analysis indicates that large warehouses were the most profitable projects. Warehouses provide the highest average dollar amount of profits with the lowest variance in profit margin. Profit margin analysis provides evidence that SteelFab has done well in identifying and accounting for the differences in costs amongst buildings. The largest source of error appears to lie in buildings within the “other” category. While this is to be expected due to great variation in projects, attempts to mitigate these additional risks should be made. For example, having a senior estimator specialize in these more difficult estimates as well as closely evaluating the entire production process from start to finish for “other” projects.

This study can be used as a guide for the firm’s analysis going forward. The statistical insignificance of the coefficient on wage presents an opportunity for interesting further research. Data on the actual wage rate associated with each job would be a good starting point. If this were to fix the problem, then a logical next step would be to check for systematic errors in the estimation of labor. Additionally, if overhead associated with the fabrication of different building types varies, then SteelFab might consider using a different labor rate for each building type in their estimates.

The model seems to fit the data well. However, other model types could be tested to check for an improved fit. Testing the relationship between elasticities of substitution between inputs would also be an interesting point of emphasis for future studies.

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Table 3.1: Descriptive Statistics of Variables (n=143)

Variable	Mean	Standard Deviation	Minimum	Maximum
Final project cost (Dec. 2018 USD)	$1,946,953	$3,085,990	$11,774.94	$25,094,642
Steel output (tons)	703.58	1,202.97	.44	10,691.67
Price of steel inputs (Dec. 2018 USD per ton)	$1,013.10	$152.20	$768.90	$1,915.54
Wage (Dec. 2018 USD per hour)	$54.58	$3.32	$43.84	$58.83
Price of freight (Dec. 2018 USD per ton)	$132.94	$228.34	$28.00	$1,940.00
Price of Erection (Dec. 2018 USD per ton of output)	$2,046.81	$3,510.44	$0.00	$23,134.33
Costs of Misc. Metal (Dec. 2018 Thousand USD)	$13.267	$21.370	$0.00	$154.461
Change order (=1 if the project contains a change order)	.8014	.3982	0	1
Change order	$263,331	$856,170	- $53,637	$6,385,920
DifBidCon (=1 if the final estimate differs from original contract price by $\geq$ 3%)	.1189	.3248	0	1

Table 3.2: Descriptive Statistics for Project Region and Project Type (n=143)

Variable	Mean	Min.	Max.
Mid-Atlantic (=1 if the project is in VA, MD, or DC)	.1399	0	1
North (=1 if the project is in NY, NJ, PA, or OH)	.0699	0	1
South (=1 if the project is in AL, GA, FL, NC, SC, or TN)	.7622	0	1
West (=1 the project is in AZ, CO, OK, or UT)	.0280	0	1
New Construction (=1 if the building is new)	.7063	0	1
Renovation (=1 if the project is a renovation or expansion)	.2937	0	1
Hospital (=1 if the project is a hospital)	.1259	0	1
Office (=1 if the project is an office)	.1748	0	1
Other (=1 if the project is an "other" building)	.3147	0	1
Warehouse (=1 if the project is a warehouse)	.3846	0	1
HospRen (=1 if the project is a hospital and renovation)	.0909	0	1
OfficeRen (=1 if the project is an office building and renovation)	.0699	0	1
OtherRen(=1 if the job is a "other" project and a renovation)	.0839	0	1

Table 5.1: Model of SteelFab Project Costs (ln of costs)

Variable	Estimate	Robust SE	t-Value	P > |t|	95% CI	
lnTons	.773	.045	17.27	0.000	.685	.862
lnSteelPrice	.325	.240	1.36	0.177	-.149	.799
lnWage	.358	.583	.61	0.540	-.796	1.513
lnFreightPrice	.238	.108	2.19	0.030	.023	.452
lnErectionPrice	.059	.018	3.04	0.003	.019	.091
MiscCost	.006	.002	2.93	0.004	.002	.010
Project Region						
MidAtlantic	.084	.102	0.83	0.411	-.117	.285
North	.261	.212	1.23	0.222	-.159	.680
West	-.361	.288	-1.24	0.216	-.928	.212
Project Type						
Hospital	.551	.201	2.74	0.007	.153	.948
Office	.089	.104	0.85	0.396	-.118	.294
Other	.284	.106	2.69	0.008	.075	.493
Renovate	.028	.262	0.11	0.916	-.490	.545
HospRen	-.373	.344	-1.08	0.281	-1.054	.308
OfficeRen	.148	.313	0.47	0.638	-.472	.768
OtherRen	.098	.303	0.32	0.747	-.502	.698
Change Order	.342	.104	3.29	0.001	.136	.549
DifBidCon	.173	.095	1.83	0.070	-.014	.361
Constant	3.839	3.218	1.19	0.235	-2.530	10.208
n = 143	F (18, 124) = 154.57	Prob F > 0 = 0.0000	R-Squared = 0.9443	Root MSE = .38045		

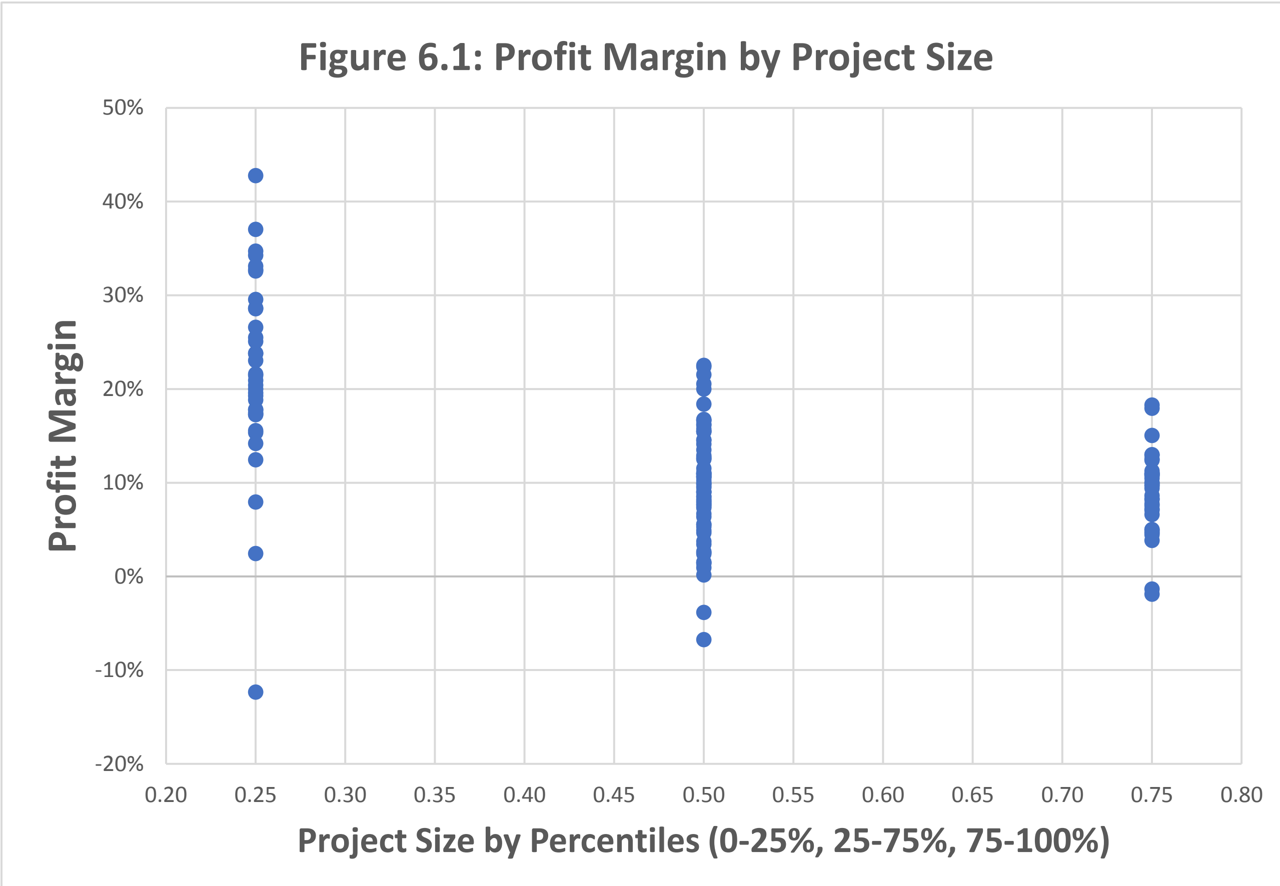
Figure 6.1: Profit Margin by Project Size
50%
40%
30%
20%
10%
0%
-10%
-20%
Profit Margin
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
0.80
Project Size by Percentiles (0-25%, 25-75%, 75-100%)

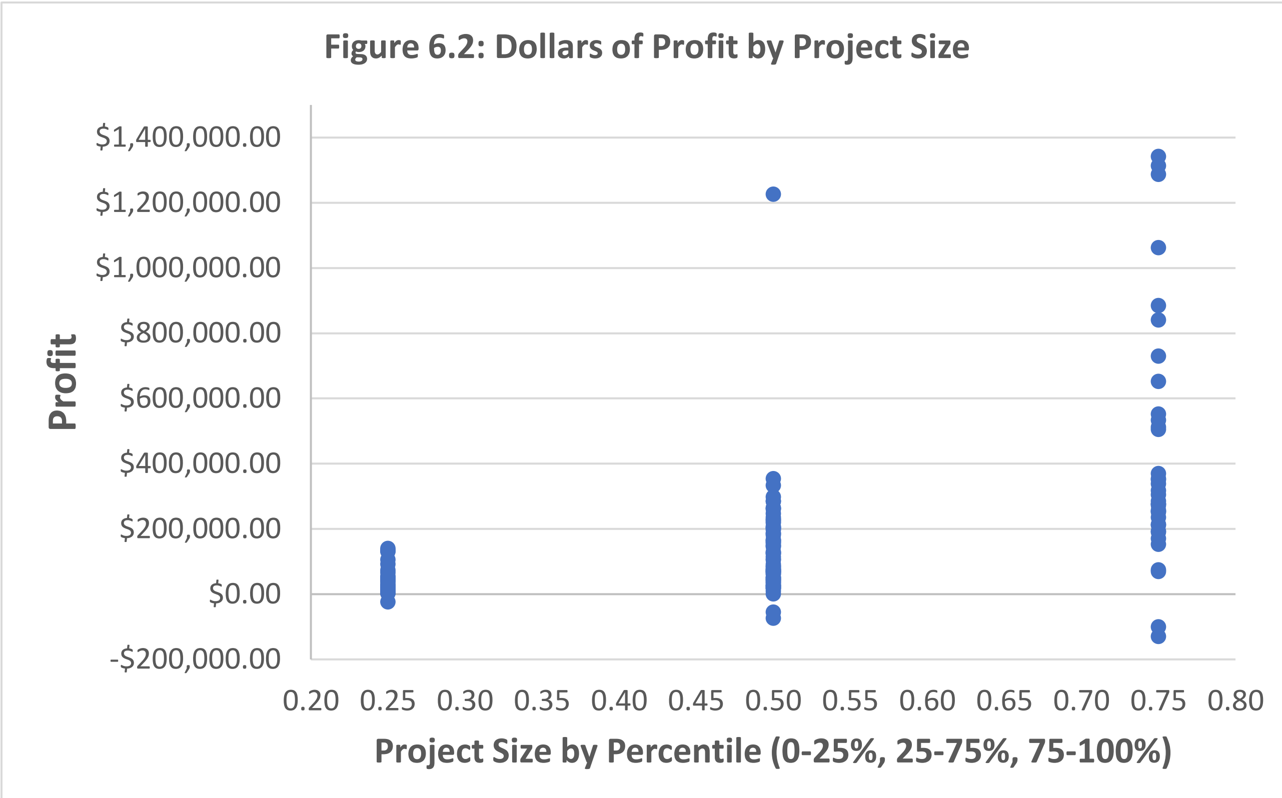
Figure 6.2: Dollars of Profit by Project Size
Profit
$1,400,000.00
$1,200,000.00
$1,000,000.00
$800,000.00
$600,000.00
$400,000.00
$200,000.00
$0.00
-$200,000.00
0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60 0.65 0.70 0.75 0.80
Project Size by Percentile (0-25%, 25-75%, 75-100%)

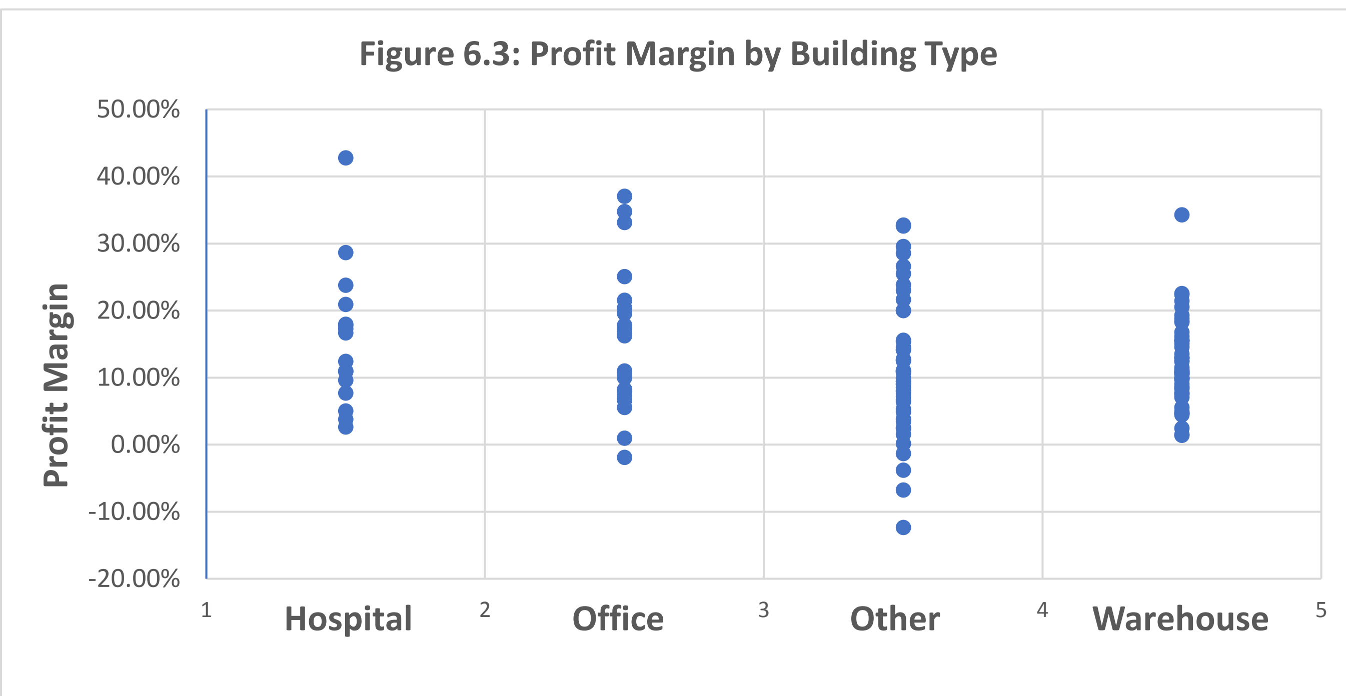
Figure 6.3: Profit Margin by Building Type
Profit Margin
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
-10.00%
-20.00%
1
Hospital
2
Office
3
Other
4
Warehouse
5

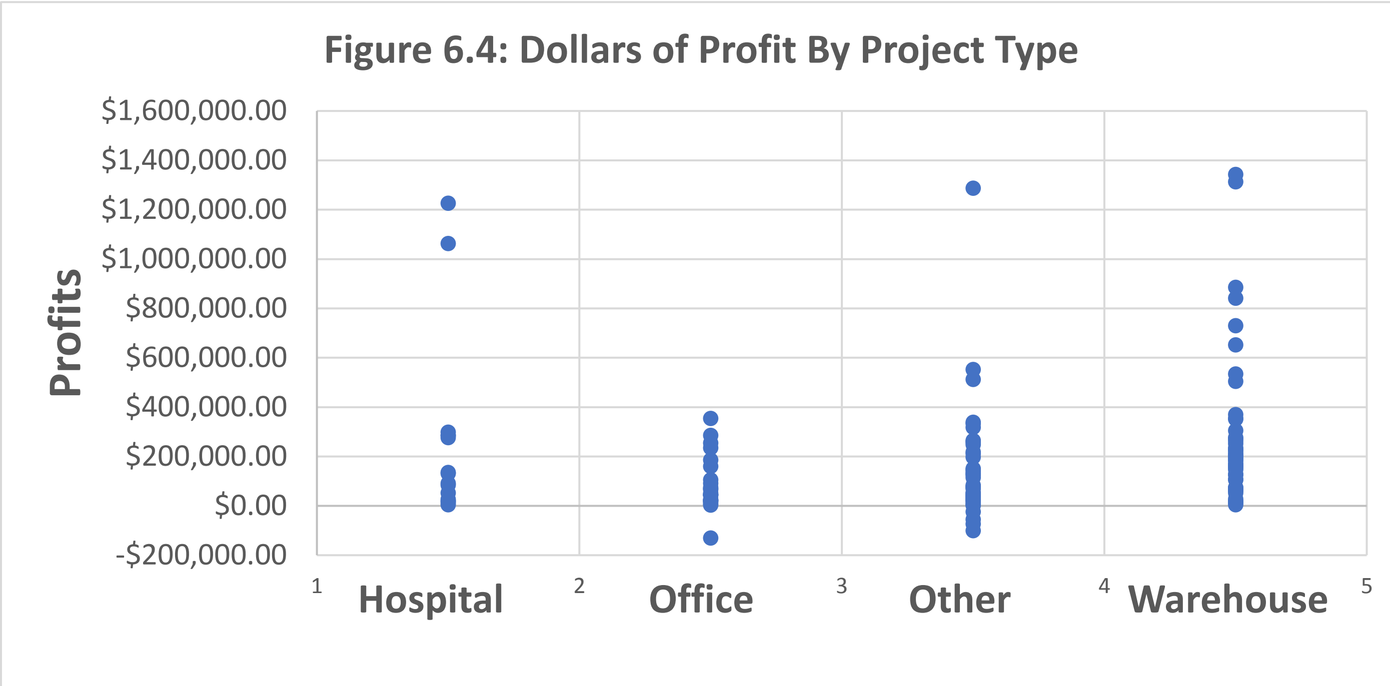

Figure 6.4: Dollars of Profit By Project Type
Profits
$1,600,000.00
$1,400,000.00
$1,200,000.00
$1,000,000.00
$800,000.00
$600,000.00
$400,000.00
$200,000.00
$0.00
-$200,000.00
1
Hospital
2
Office
3
Other
4
Warehouse
5