Cost Risk for Firm Fixed-Price Contacts

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Abstract

The terms "cost risk" and "firm fixed-price contracts" seem contradictory. By design the contractor bears all risk under a firm fixed-price (FFP) contract. In spite of this, overruns often occur, and contractors have recourse to a Request for Equitable Adjustment (REA) when cost grows beyond the contract value. We present statistics on cost overruns for FFP contracts, some of which are significant, and show how to model risk for such contracts.

Introduction

At first glance the terms "cost risk" and "firm fixed-price contracts" may seem contradictory. Firm Fixed- Price (FFP) contracts are intended to place the onus of the risk of cost growth onto the performing contractor. As a government agency this is generally interpreted that the contractor bears all financial risk. Thus the potential for cost growth on FFP contracts is typically not considered when setting budgets or analyzing cost risks. Contractors include their profit margin in the FFP contract, since that is how they make a profit. However, despite these considerations, it is sometimes the case that the government eventually pays for cost overruns on FFP contracts. There is a process by which contractors can apply for an equitable adjustment. This can occur because the fixed price is tied to the statement of work. If the government adds requirements, the cost can overrun the agreed to amount, leading to a request for equitable adjustment. Note that in this context, when we discuss cost growth and cost risk for FFP contracts, we are looking at the issue from the government perspective, that is the amount that the government ends up bearing, not just the amount that the contractors incurs.

We have conducted a quantitative analysis of 1,729 Missile Defense Agency Firm Fixed Price (FFP) contracts concludes that while 88% of the contracts had no cost or scope growth, 12% did, with an average growth of approximately 6%. This is much lower than the 50% average cost growth for cost-plus development programs (Smart 2015), but it is still significantly greater than zero. Also the fact that 88% of the FFP contracts do not exhibit cost growth is much less than the 18% for cost-plus development programs found in a recent study (Smart 2015). That is while 82% of cost-plus development program overrun their initial budget, only 12% of FFP contracts grow in cost. Fitting a distribution to these cost growth data we find that the best fitting distribution is a beta distribution. This is also quite different from the lognormal distribution that has been found to fit cost growth data for cost plus contracts for development programs well (Smart 2015).

Methodology

An ad hoc report of Missile Defense Agency FFP Contracts was retrieved from the Contract Writing System Database, Standard Procurement System (SPS) Procurement Desktop-Defense (PD^2) . PD^2 lets you automate and control your own procurement process in an integrated desktop environment that enables paperless and more efficient contracting. The intuitive desktop interface provides graphical document management, electronic routing and approval, web-based reference library with both federal and DoD acquisition regulations, the Federal Procurement Data System (FPDS) and ad hoc reports. There are 1,729 contracts in the database with face value at award ranging from $100 to $559 million and face value at completion ranging from $100 to $894 million. Figure 1 contains a scatterplot of face value at award compared with the percent increase in cost.

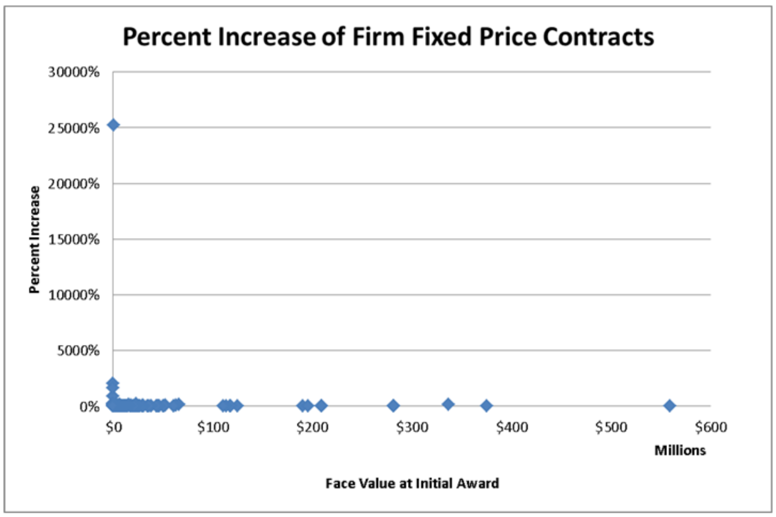

Figure 1: Percent increase of Firm Fixed Price Contracts vs Face Value at Award

The vast majority of firm fixed price contracts have little to no cost growth. Specifically 88% of the contracts experienced zero growth.

% Growth	Number of Contracts	% of Total
0% Growth	1530	88%
1-10% Growth	63	4%
11-20% Growth	24	1%
>20% Growth	112	6%
Total	**1729**	

Figure 2: Summary of % Growth of MDA Firm Fixed Price Contracts

The contracts were totaled in initial value, final value, and total percent change. This is summarized in Figure 3. Even though the vast majority of the contracts do not experience overruns, the total increase is 30% in value over the initial amount.

Total of initial value	$5,911,374,537
Total of final value	$7,737,065,887
Change in Value	$1,825,691,350
% Change in Value	30.884%

Figure 3: Total Change in Value of MDA Firm Fixed Price Contracts

Investigating Outliers

Looking at Figure 1 a clear outlier exists. It had a starting value of $698,393 and a Final Value of $176,091,965. That is a 25,514% growth!

After researching the program there were two major modifications after award, one for $31,674,868 and one for $89,424,159. This contract was time sensitive and mission critical which required awarding the contract before negotiations were complete and update as negotiations were finished. To limit the liability of the government the starting contract value is kept as low as possible until final award. Thus the two initial major modifications should have been in the initial contract value. After updating the initial value to $121,797,420, which is more indicative of the contract, there is 45% cost growth. The rest of the modifications to the contract were a result of requests for equitable adjustments, requirements growth, and rate updates which are the types of updates this study attempts to quantify.

Adjusting the data point above the scatterplot was updated and shown in Figure 4.

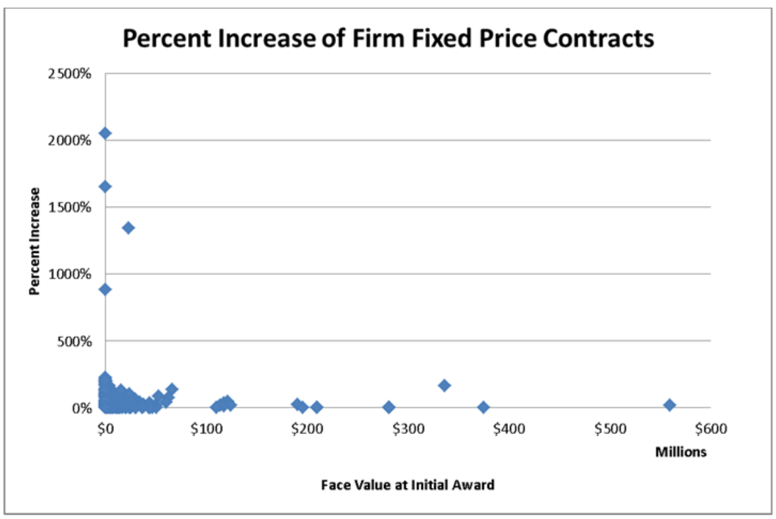

Figure 4: Figure 1 with one outlier adjusted

Now there are 4 data points that need to be investigated further to decide if they are valid (2,050% increase, 1,650% increase, 1,345% increase, and an 881% increase.)

The 2,050% increase had a similar award situation and has been adjusted to 198%. There was a large project that was added to the contract after execution begun that makes up a large part of the 198% increase, that was left in as requirements creep.

The 1,650% increase had three awards of options that should have been included in the original contract value. Updating its value to include those options resulted in 93% growth. Some of that growth was due to shipping rate changes and shipping address changes. This was a transportation contract so we expect those to be significant cost drivers.

The 1,345% increase was partly the result of an accounting error on the final value of the contract. When fixed the increase was reduced to 223%. The majority of the changes making up the 223% were extending the contract multiple times.

The 881% increase had an award of multiple options that should have been part of the original contract value. When updated it has a .3% increase which is more typical of growth experienced in fixed price contracts.

After adjusting the data for the above outliers the scatterplot was updated and presented in Figure 5.

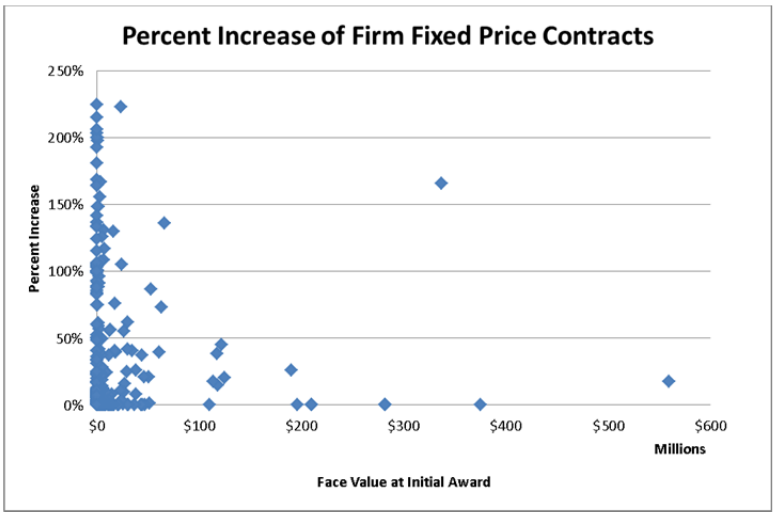

Figure 5: Figure 1 with 5 Outliers Corrected

Figure 6 provides a histogram of the frequency of the % increase. As can be seen most Firm Fixed Price Contracts experience no cost growth. However, there are contracts that experience cost growth and thus the risk of growth does need to be accounted for in a thorough risk analysis. After accounting for the outliers the total contract value increase over the initial contract value is 24%, a significant amount for firm fixed price contracts that supposedly mean little risk to the government.

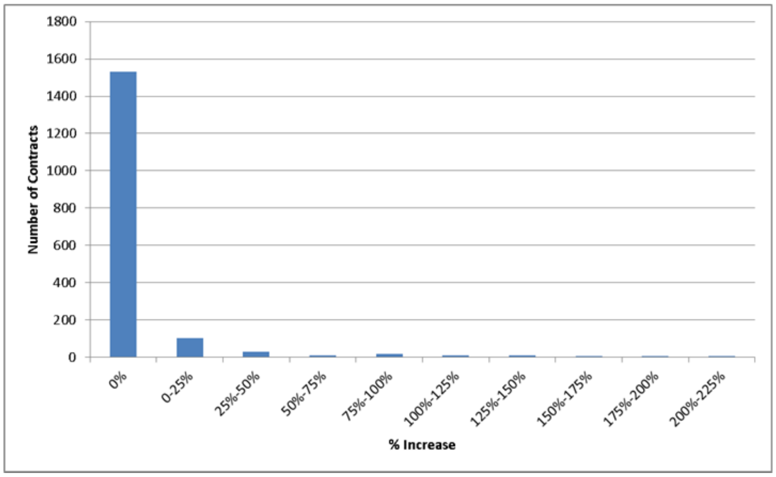

FIGURE 6: Summary of cost growth data for 1729 MDA Firm Fixed Price Contracts

On reviewing the data above and other contract change logs the cost growth on FFP contracts can be explained by a number of different reasons. First, Request for Equitable Adjustment (REA). Per the Contract Pricing Reference Guides Volume 4: (DAU, 2013)

> Equitable adjustments are necessitated by some modification of the contract effort. In general, these contract modifications can be defined in one of three ways:
> •Addition of work to the contract.
> •Deletion of work from the contract.
> •Substitution or replacement of one item of work for another (i.e., an addition with a related deletion).
> This modification may come from an overt change in Government requirements or it may come from a change in the conditions surrounding the contract (e.g., differing site conditions or late delivery of Government-furnished property).

In practical terms a REA is the contractors request to be compensated when a government manger tells them to perform additional requirements without going through the formal contracting process.

The next most prevalent is requirements creep. These are changes to the base requirements of the contract after initial award. Examples of these include increase quantity; decrease quantity purchased; add additional safety constraints; add additional cybersecurity constraints. Because these are changes to the base contract they all result in cost uppers or at best no cost change, even when buying less.

The last change observed in the survey was administrative changes that drove cost increases. Above one of the listed changes for the contract was a change of mailing address and shipping method.

It is important to note that despite these changes there were not any cases in which the Firm Fixed Price contract was less than awarded. The way a Firm Fixed Price contract is structured is that the contractor gets to keep the entire negotiated price regardless of the cost of the contract. In the case that the cost exceeds the negotiated price, the contractor is supposed to cover the cost of the overrun from company profits. However, in practice, and as evidenced by the data, many times the contractor will be able to point to a change directed by a government manager and submit an REA rather than bear the cost themselves.

Quantifying Cost Growth

Given the survey and the data presented above there is strong evidence that Firm Fixed Price contracts experience cost growth, despite the concept that the contractor will bear all risk. quantify the risk with a probability distribution so that it can be incorporated into the thorough risk analysis that MDA performs on all of its cost estimates.

The cost growth data were fit to a variety of standard probability distributions using Crystal Ball, an Excel add-in. Crystal Ball uses maximum likelihood estimation to fit probability distributions, which works well when a large number of data points are available, as in this case. To assess the fit of the distributions Chi-Square and Kolmogorov-Smirnov (K-S) statistics were calculated for each distribution. The statistics for the top three, as ranked by the Kolmogorov-Smirnov (K-S) statistic, are displayed in Table 2.

Each of these tests can be thought of as a measure of deviation from a perfect fit for the data. Thus, for them, a smaller test-statistic value indicates a better fit. These tests focus on slightly different aspects of a distribution's fit. Kolmogorov-Smirnov measures the maximum difference between the actual data and the fitted distribution, and Chi-Square is a sum of squares deviation measure.

Even though the normal distribution has the best rank according to the Kolmogorov-Smirnov test, that does not mean we should unequivocally accept the normal distribution as a good representative of the underlying data. When it comes to statistics, we can never positively prove a hypothesis, such as "the cost growth data fit a normal distribution." We can, however, disprove hypotheses with data. Thus, the best we can hope to do in distribution fitting is to fail to reject a given hypothesis.

Distribution	Kolmogorov-Smirnov	Chi-Square
Normal	0.4737	49203.0086
Student's t	0.4764	47200.5147
Lognormal	0.5099	48477.0896

Table 2: Comparison of best-fitting distributions for cost-growth data

For each test, a critical value is determined based on the degrees of freedom of the data. For the Chi-Square test, the critical value given the number of degrees of freedom is higher than the Chi-Square test statistic of 74.22, so we reject the normal as well as the others. The Kolmogorov-Smirnov critical value at the 5% significance level is:

$$\frac{1.36}{\sqrt{N}} = \frac{1.36}{\sqrt{1729}} = .0327$$

Comparing this to the Kolmogorov-Smirnov statistics shown in Table 2, all of the distributions can be rejected. Thus all three of the best fitting standard distributions, per Crystal Ball Goodness of Fit Algorithm, reject the null hypothesis that the data fits that distribution.

Beta distributions have a unique ability to be able to be reshaped to fit many unique distributions by varying the parameters Alpha, Beta, Min, and Max. Using an Excel add in "solver" to reduce the squared deviation between the data set and the beta distribution one gets a Beta Distribution with parameters described in Table 4. Table 3 is the four moments of the MDA Firm Fixed Price data and Table 4 is the beta distribution inputs from the Excel Solver tool.

Mean	0.0589
Standard Deviation	0.2526
Kurtosis	32.8695
Skewness	5.4893

Table 3: Descriptive statistics from Firm Fixed Price dataset

Alpha	0.02875
Beta	1.046737
Min	0
Max	2.225

Table 4: Beta Distribution Parameters

Figure 7 contains a comparison between the raw data and the beta and normal distribution fits. We can see that the beta distribution fits much better than the normal, which was proposed as the best fit by Crystal Ball. Clearly the beta distribution captures the high probability that there would be zero growth, while allowing for some probability of large cost growth as evidenced by the tail. Table 5 provides the goodness of fit tests used on the distributions above. Based on the statistics we fail to reject the null hypothesis that the Beta distribution describes the cost growth data evidenced by Fixed Price Contracts.

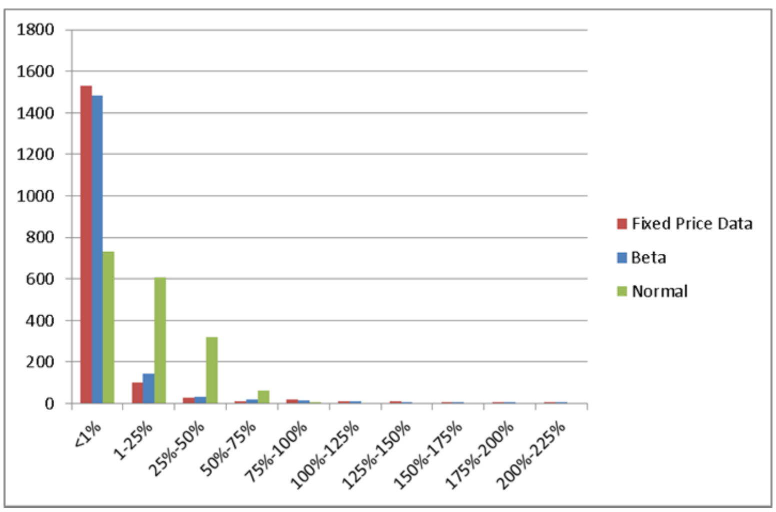

Figure 7: Histogram comparing Fixed Price Data to Beta and Normal distributions

Figure 8 and Figure 9 compare the empirical data to the beta distribution. Visually it appears to be a clear fit.

Distribution	Kolmogorov-Smirnov	Chi-Square
Beta	0.027616	1

Table 5: Beta distribution goodness of fit tests

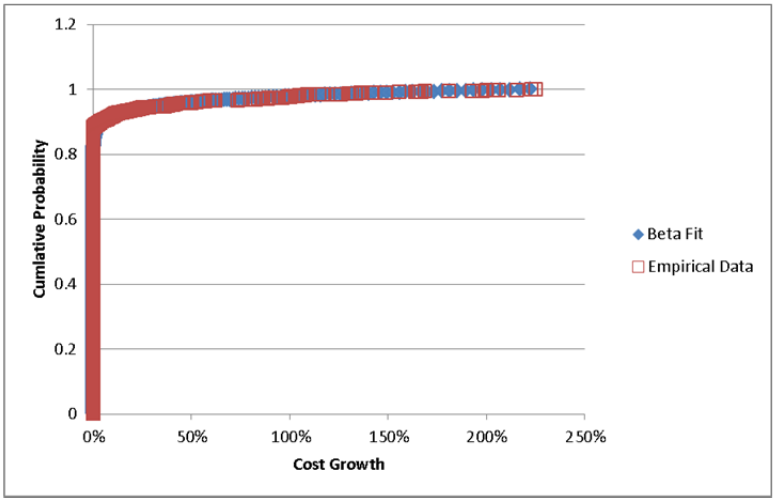

Figure 8: Comparison of Beta Fit to Empirical data – full data set

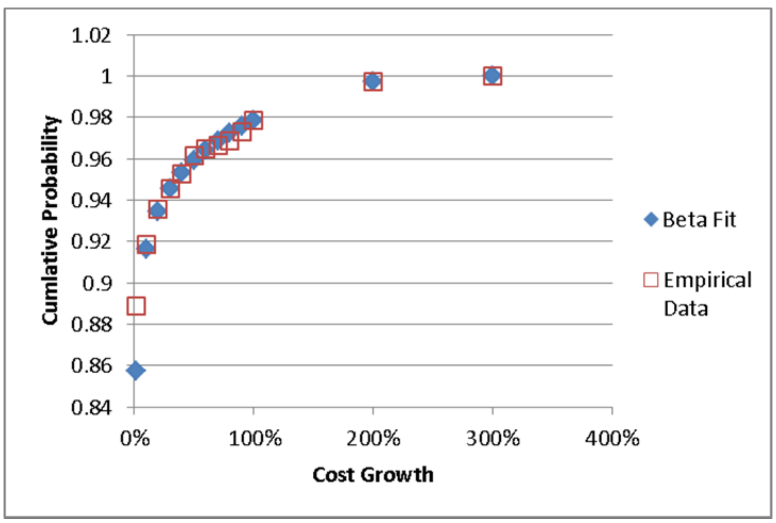

Figure 9: Comparison of Beta Fit to Empirical data – summarized data to investigate fit of tail

Application

When building cost estimates based around FFP contract values we have shown that it is no longer prudent to assume no risk of cost growth. For application purposes it is recommended to multiply a FFP Contract value by 1 + FFP risk factor in which the FFP risk value has a mean of 5.89% and follows a beta distribution as defined above. This is especially valuable when using inputs based risk analysis such as Method of Moments or Monte Carlo Simulation and can specify an uncertainty distribution.

Conclusion

We have found that there is strong evidence that cost overruns (that the government pays) occur on firm fixed-price contracts about 12% of the time, and that the average overrun is 6%. We need to model this risk when estimating costs for FFP contracts. We have provided a beta distribution whose parameters can be used as a default cost risk distribution around FFP contract values in the absence of any additional insight.

Acknowledgments

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