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Using the Steel Vessel Material-cost Index to Mitigate Shipbuilder Risk

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USING THE STEEL VESSEL MATERIAL-COST INDEX TO MITIGATE SHIPBUILDER RISK

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Using the Steel Vessel Material-cost Index to Mitigate Shipbuilder Risk

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Abstract

This paper describes how the US Navy structures fixed-price and fixed-price, incentive-fee shipbuilding contracts and how labor- and material-cost indexes can mitigate shipbuilder risk in either type of contract. The Navy frequently uses the Steel Vessel material-cost index, a Bureau of Labor Statistics-derived cost index based on the mix of materials in a typical commercial cargo ship constructed in the 1950s. The Steel Vessel Index has excessive weighting on iron and steel, thereby providing shipbuilders with a mismatch between their actual and the Index-assumed material-cost structure. We recommend the Navy use a material-cost index with more up-to-date weightings.

Introduction

The Navy wants to provide its shipbuilders with appropriate incentives to produce militarily effective vessels at minimum cost to the Navy.

Fixed-price contracts provide incentive to a shipbuilder to produce at minimum cost. After contract award, cost savings the shipbuilder can implement flow directly to the shipbuilder, resulting in higher profit. Conversely, cost overruns are borne by the shipbuilder, resulting in lower-than-anticipated profits.

Fixed-price contracting becomes problematic, however, when a shipbuilder is forced to bear risk outside of its control. For instance, ship construction requires material inputs like steel, wire, cable, and myriad others. If the global prices of these commodities rise, a fixed-price shipbuilder will have lower profits (or increased losses) external to the shipbuilder's efforts.

Ultimately, the Navy can induce a shipbuilder to agree to any arrangement, including having the shipbuilder bear material-cost risk, by offering the shipbuilder a high enough price. But it is likely to be preferable, at least ex ante, for the Navy to dissipate risk external to its shipbuilder in order to pay less for the systems the Navy needs.

Conversely, the Navy should not fully immunize a shipbuilder against risks within the shipbuilder's control, e.g., if the shipbuilder's own failures cause a cost overrun. In such a case, the shipbuilder should incur at least a portion of the loss. Of course, it can sometimes be difficult to distinguish problems within a shipbuilder's control versus those caused or exacerbated by Navy decisions (e.g., changing requirements) versus those related to external issues (e.g., the rising global price of steel). The Navy uses labor- and material-cost indexes to attempt to correct for several significant cost risks outside its shipbuilders' control. The indexes reflect industry- or economy-wide costs, not the costs of the specific shipbuilder.

How the Navy uses Labor- and Material-cost Indexes

In this section of the paper, we present illustrative examples of how the Navy uses labor- and material-cost indexes. We start with a highly oversimplified example of a fixed-price contract to illustrate the basic intuition. Subsequently, we turn to an enhanced (though still less complex than reality) example of a contract more in accord with current Navy practices. This latter example is a Fixed-Price, Incentive Fee (FPIF) contract. An FPIF contract is no longer a "pure" fixed-price contract in that it requires the Navy and the shipbuilder to share cost changes from the negotiated level with incentives and disincentives for underruns and overruns (whereas a textbook fixed-price contract would not). The shipbuilder's actual costs are considered in an FPIF contract; they are not in a fixed-price contract.

A Very Simple Example. Let us suppose the Navy signs a fixed-price contract for a $220 million ship on January 1, 2007, with completion scheduled for January 1, 2010. If $100 million of the payment is to cover expected labor costs, another $100 million is to cover expected material costs, and the final $20 million is intended to be contractor profit. Of course, the actual cost the shipbuilder incurs determines the shipbuilder's profit. Figure 1 shows the shipbuilder's profit as a function of the actual labor and material cost of the ship. Increasing costs reduce shipbuilder profits dollar-per-dollar.

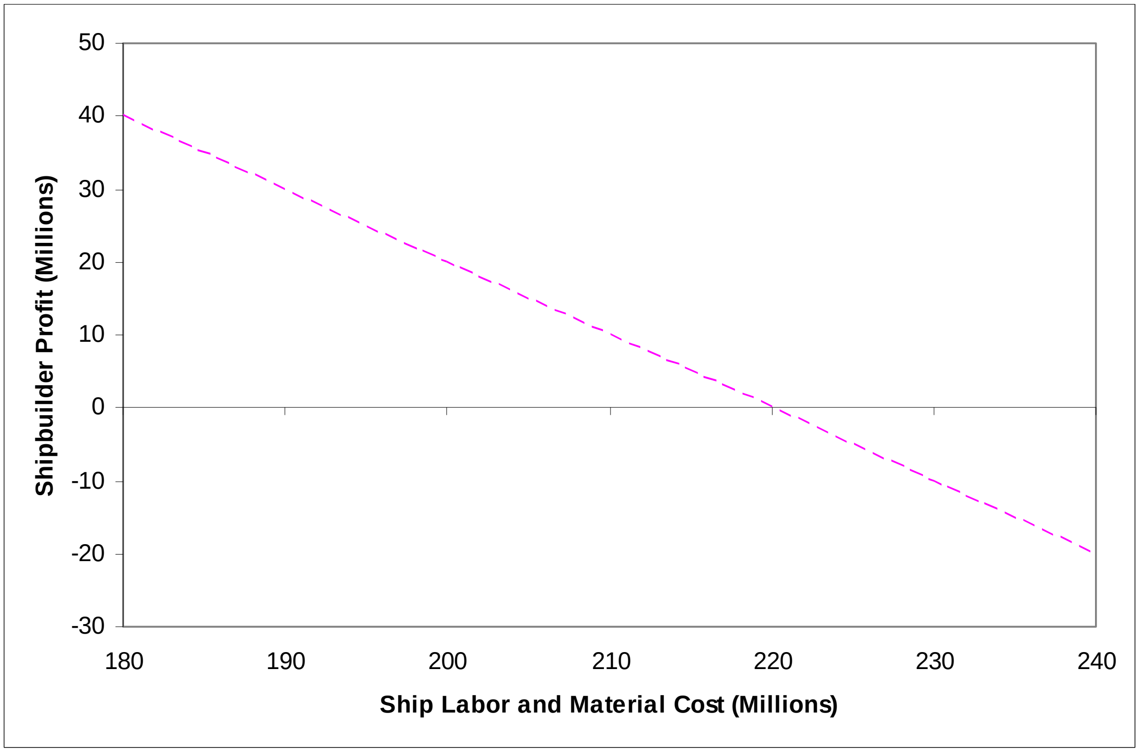

Figure 1. Shipbuilder Profit as a Function of Labor and Material Cost with a Fixed-price Contract

Adding material-cost indexes to this fixed-price contract would protect the shipbuilder against exogenous cost risk.

Let us also suppose, during the period 2007-2010, the external labor-cost index designated in the contract goes up 5%, while the designated material-cost index goes up 20%. Then the Navy's actual payment to its shipbuilder would be $245 million ($105 million for labor, $120 million for materials, $20 million in intended or target profits—assuming the profit level does not increase with the indexes). The shipbuilder's actual profit would then go up and down based on whether their actual cost growth was above or below the indexes'. Obviously, it is of central importance that the cost indexes are agreed upon up front.

If, on the other hand, the labor-cost index had risen 5% while the material-cost index had fallen 10%, the Navy's payment to the shipbuilder would be $215 million ($105 million in labor, $90 million in materials, $20 million for target profit). Again, actual profit would depend on whether the shipbuilder's total costs had fallen less than or more than the indexes suggested.

Both this example and the one that follows are over-simplified. Both examples assume all labor is incurred and material purchased on the last day of the contract. If one alternatively assumes the postulated inflation, labor hours, and material purchases occur uniformly between 2007 and 2010, the average inflation rate would be half as large. In reality, material purchases peak before labor hours are incurred, so there are two cost timing distributions to account for. Actual Navy escalation clauses calculate these effects on actual costs incurred monthly. The Appendix discusses such an enhancement.

A More Realistic Example. The Navy does not generally write shipbuilding contracts that are as simple as the preceding example. Instead, the norm is to use FPIF contracts with "compensation adjustment clauses" or "escalation provisions" to:

- Ensure the incentive provision operates independent of outside economic forces that impact shipbuilder costs.
- Keep the shipbuilder from including contingent amounts in its price to cover economic uncertainty associated with external cost pressure.

In this approach, subsequent changes in specified cost indexes result in payments (or refunds) tied to the shipbuilder's actual labor and material costs incurred. Notice this approach is no longer a "pure" fixed-price contract; shipbuilders' actual costs are considered. FPIF contracts actually operate as cost-type incentive contracts within a certain range of costs.

We can consider a similar example as above with the Navy signing a contract for a ship on January 1, 2007, with completion scheduled for January 1, 2010. It is anticipated $100 million will be spent on labor and another $100 million on material. Let us suppose the Navy also agrees to a 10% target profit rate and a sharing ratio of 50/50 for increases or decreases in cost. Figure 2 illustrates shipbuilder profit under this FPIF contract versus the preceding fixed-price case (prior to consideration of cost-index issues). Since this FPIF contract has cost-change sharing between the Navy and the shipbuilder, the FPIF line is flatter.

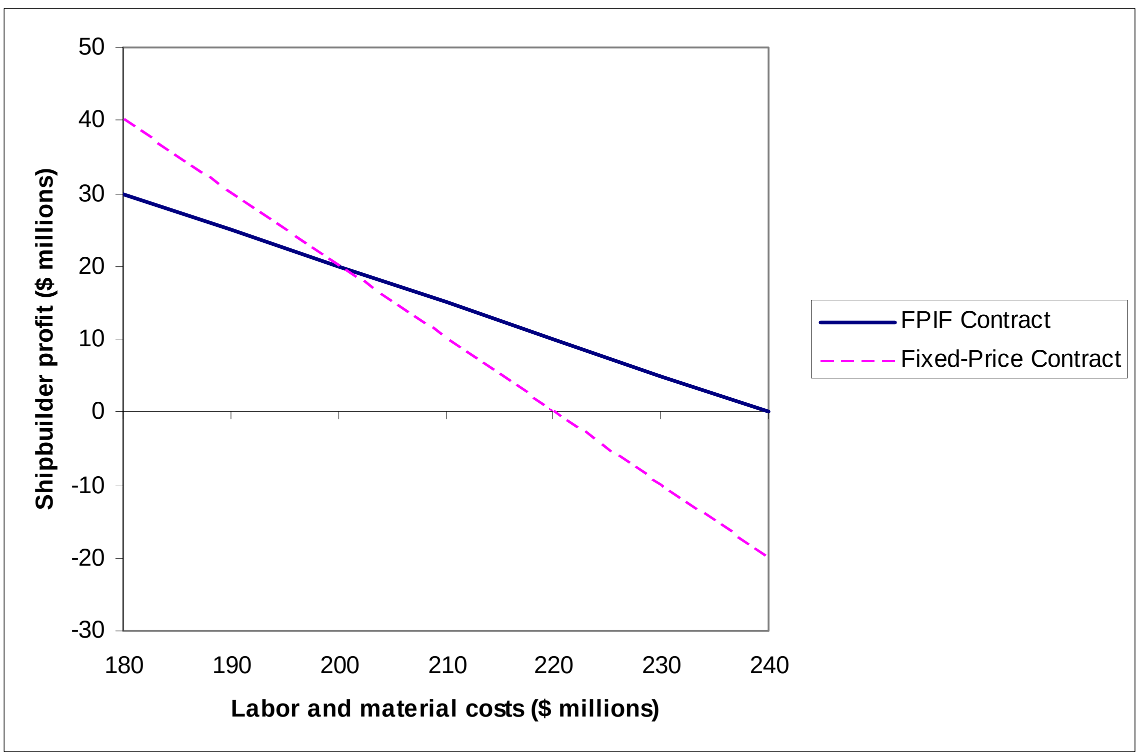

Figure 2. Shipbuilder Profit as a Function of Labor And Material Cost with Different Contract Structures

As above, it would enhance realism to include labor- and material-cost indexes into this contract.

Let us suppose, during the period 2007-2010, the labor-cost index designated in the contract goes up 5%, while the designated material-cost index is up 20%. We assume base period labor and material costs of $100 million each. If the shipbuilder's actual labor cost was $105 million, the Navy would pay a compensation adjustment of $5 million ((0.05 divided by 1.05) multiplied by $105 million).[1] If actual material costs turned out to be $115 million, the Navy would make a material compensation adjustment of $19.17 million ((0.20 divided by 1.20) multiplied by $115 million). The "de-escalated base cost" of the ship would be $195.83 million (the actual $105 million plus $115 million less the compensation adjustments of $5 million and $19.17 million). The $4.17 million decrease between the initial base cost and the de-escalated base cost would translate into a $2.08 million increase in profit for the shipbuilder given the assumed 50/50 cost change-sharing ratio. The shipbuilder is rewarded because actual material costs did not rise as rapidly (+15%) as the material-cost index (+20%).

The Navy's actual payment to the shipbuilder would be comprised of $195.83 million in de-escalated base cost, $5 million in labor escalation payments, $19.17 million in material escalation payments, $20 million in target profit, plus $2.08 million in incentive profit—totaling $242.08 million. Shipbuilder profit would be $22.08 million.

By contrast, holding the shipbuilder's incurred costs the same as above, suppose the labor-cost index had again risen 5% while the material-cost index fell 10%. The labor compensation adjustment would remain $5 million ((0.05 divided by 1.05) multiplied by $105 million). The material compensation adjustment would now be a reimbursement from the shipbuilder of $12.78 million ((-0.10 divided by 0.90) multiplied by $115 million). The "de-escalated base cost" of the ship would be $227.78 million ($105 million plus $115 million minus $5 million plus $12.78 million). This increase in the de-escalated base cost would result in a $13.89 million profit penalty for the shipbuilder (50% of the difference between $227.78 million and $200 million). Then, the Navy would pay the shipbuilder $226.11 million ($227.78 million in de-escalated base cost plus $5 million in labor escalation payments less a $12.78 million material de-escalation reimbursement plus $20 million in target profit less a $13.89 million incentive profit penalty). The shipbuilder profit would be $6.11 million.

As in the "Very Simple Example," we have ignored realistic timing issues, e.g., the fact that median material cost probably precedes the median labor cost and that neither cost is incurred, on average, in 2010. The Appendix discusses the effects of incorporating labor and material-cost time-phasing.

Figure 3 summarizes the differential results of these examples, holding fixed that the labor-cost index increased 5%, while realized shipbuilder costs were $115 million for material and $105 million for labor. Not surprisingly, when the shipbuilder spends more on material than included in the original price while the overall material market has falling prices, the cost disincentive built into the contract reduces the Navy's payment and, hence, the shipbuilder's profit. (The shipbuilder would have performed very poorly if it paid $115 million for material while material prices were, on average, falling.)

[1] For expositional simplicity, we are assuming actual labor costs match the increase in the labor-cost index, allowing us to concentrate on material-cost issues.

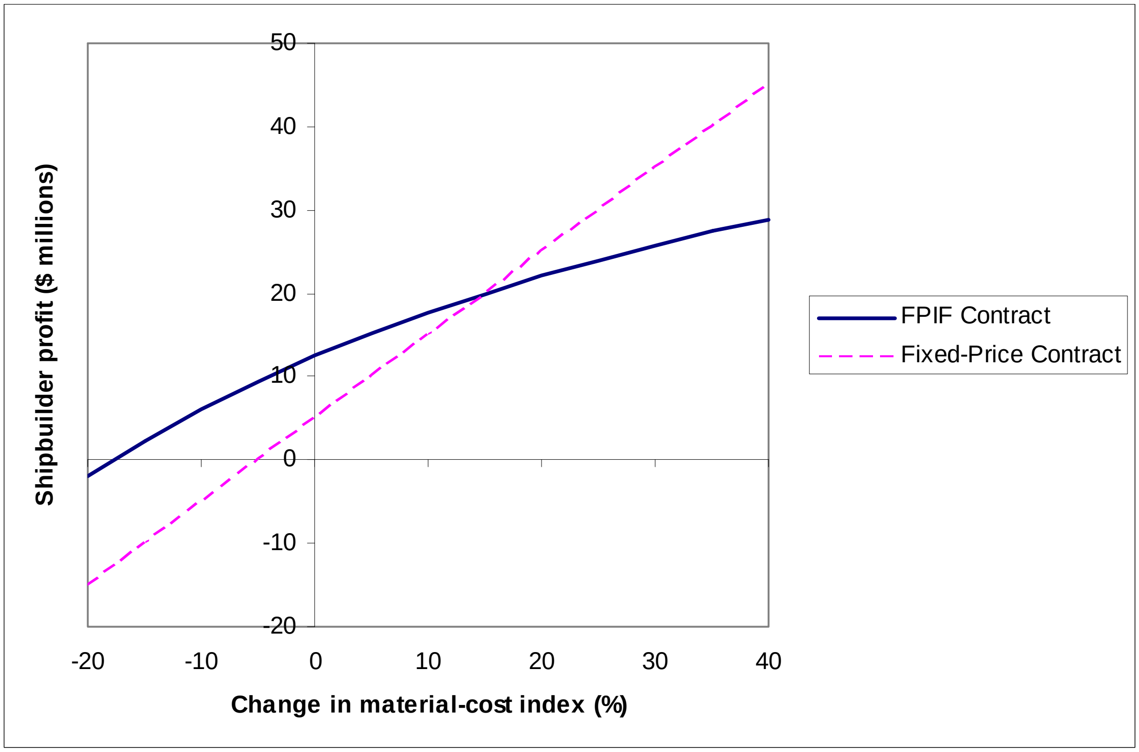

Figure 3. Shipbuilder Profits Are Greater When the Material-cost Index Rises More, Realized Costs Held Constant

The Fixed-price Contract line and the FPIF Contract curve cross at a 15% increase in the material-cost index. We have assumed the shipbuilder's actual material-cost increase was 15% or $15 million. If the shipbuilder can keep its actual material-cost growth below the index level, its reward is greater in the fixed-price case, in which there is no cost-change sharing with the Navy. Conversely, the shipbuilder's profit does not diminish as rapidly if its actual material costs increase more than the Material-cost Index with the FPIF contract's cost sharing.

If the shipbuilder's skillful management kept ship costs from rising as much as similar costs in the general economy, greater profits are an appropriate reward. However, if greater profits result from escalation payments calculated by an external price index that does not accurately reflect what the shipbuilder purchases, then greater profit is not warranted. Conversely, it would be unfair to penalize a shipbuilder if an inappropriate cost index declines or increases less than the shipbuilder's actual cost environment.

The Steel Vessel Index

A longtime material-cost index in Navy shipbuilding is the "Steel Vessel Index." Based on an estimate by the Maritime Administration of the mix of materials in a typical commercial cargo ship constructed in the 1950s (GAO, 1972), it is a weighted average of three Bureau of Labor Statistics (BLS) producer price indexes (45% Iron & Steel, 40% General Purpose Machinery and Equipment, and 15% Electrical Machinery and Equipment). If, for instance, the Iron & Steel price index increased 3% in a year, the General Purpose Machinery index increased 2%, and the Electrical Machinery index fell 1%, the Steel Vessel Index would increase 2% (0.45*0.03+0.4*0.02-0.15*0.01).[2]

One criticism of the Steel Vessel cost index is that it does not accurately cover the materials used in building a modern ship.[3] No modern US Navy ship, for instance, has 45% of its material costs in Iron & Steel. To combat this shortcoming, the DDG-51[4] and T-AKE[5] programs created their own material-cost indexes, using different weights on the same three underlying BLS indexes (DDG-51: 20% Iron & Steel, 43% General Purpose Machinery, 37% Electrical Machinery; T-AKE: 10% Iron & Steel, 60% General Purpose Machinery, 30% Electrical Machinery). See Pfeiffer (2006). In the preceding paragraph's example, whereas the Steel Vessel Index would increase 2%, the DDG-51 index would increase 1.09% (0.2*0.03+0.43*0.02-0.37*0.01), and the T-AKE index would increase 1.2% (0.1*0.03+0.6*0.02-0.3*0.01).

There is an additional challenge with any of these indexes: even if one correctly identified the mix of materials that went into the ship, the materials would be purchased at different stages of ship construction. Steel, for instance, is required early in the construction process. Conversely, combat systems and electrical equipment (perhaps more akin to General Purpose or Electrical Machinery) are not delivered to the shipyard and, consequently, do not become incurred costs until much later in construction. Time-phasing the mix of an overall material-cost index could provide greater fidelity. However, it is unlikely any material-cost index will completely dissipate a shipbuilder's exogenous material-cost risk.

Historically, BLS's Iron & Steel price index has been much more volatile than the General Purpose Machinery or Electrical Machinery indexes. Figure 4 displays these indexes' quarterly returns (with a positive "return" if the cost index value went up, negative if it fell) between the second quarter of 1947[6] and the fourth quarter of 2006. We also display the quarterly change in the Bureau of Economic Analysis' (BEA) Gross Domestic Product (GDP) price deflator, a measure of overall inflation in the economy.

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[2]There does not appear to be an Air Force analog to the Steel Vessel Index. Air Force procurement contracts may include BLS-based labor- or material-cost indexing, but this is done on a case-by-case basis at the discretion of the program office. There is no standard aircraft material-cost index. An aircraft's construction duration is typically much briefer than that of a ship, so inflation issues are less prominent.

[3]Indeed, criticism of the Steel Vessel Index pre-dates what we might term "modern" ships. Geismar (1975) suggests the Steel Vessel Index was ill-suited to the DD963, Spruance Class destroyer, and the LHA, Marine amphibious assault ship—two 1970s-era ship programs. (Both of these ships were very late in delivering, implying inflation issues proved to be more important than would have been the case had their production been more timely.)

[4]The DDG-51, the *USS Arleigh Burke*, is a destroyer commissioned on July 4, 1991. The moniker "DDG-51" refers to the class of destroyers of which the *USS Arleigh Burke* was the first (US Navy, 2006).

[5]"T-AKE" refers to the *Lewis and Clark* class of dry cargo/ammunition ships. The *USNS Lewis and Clark*, the *USNS Sacagawea*, and the *USNS Alan Shepard* have been delivered to the Navy; the *USNS Richard Byrd* is under construction (US Navy, 2007; Bigelow, 2007).

[6]Monthly BLS data on these cost indexes are available back to January 1947. However, the BEA GDP deflator data are only available quarterly, so we aggregated the BLS data to the quarter level.

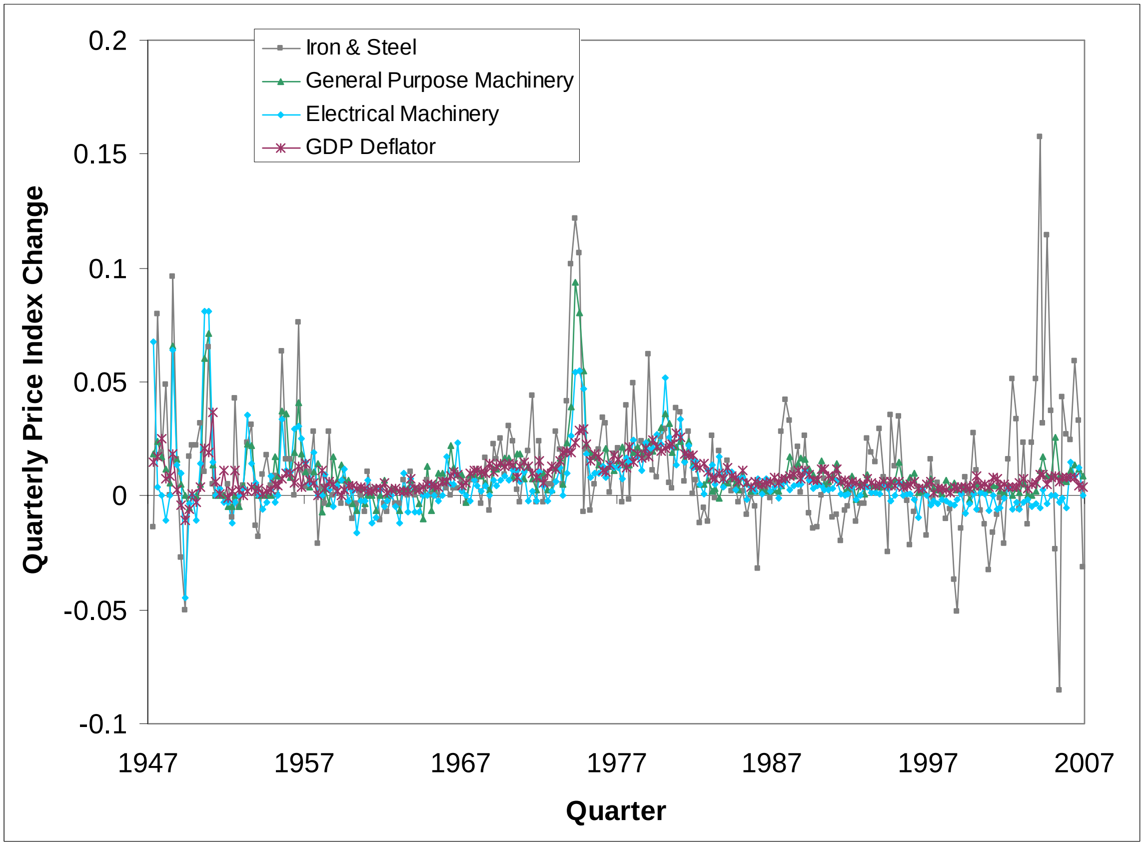

Figure 4. Quarterly Changes in Different Cost Indexes
(US DoL, BLS, n.d.; US DoC, BEA, n.d.)

Naturally, given the Steel Vessel Index's greater relative weighting of the Iron & Steel price index, it has been more volatile than the DDG-51 or T-AKE indexes. In Figure 5, we plot the standard deviation in the quarterly return and the mean quarterly return for the three ship material-cost indexes and the GDP deflator between the second quarter of 1947 and the fourth quarter of 2006.[7] The Steel Vessel Index has the greatest standard deviation in its quarterly return.

[7]None of the three ship material-cost indexes existed in 1947. But, we can use BLS data to retrospectively compute how they would have evolved.

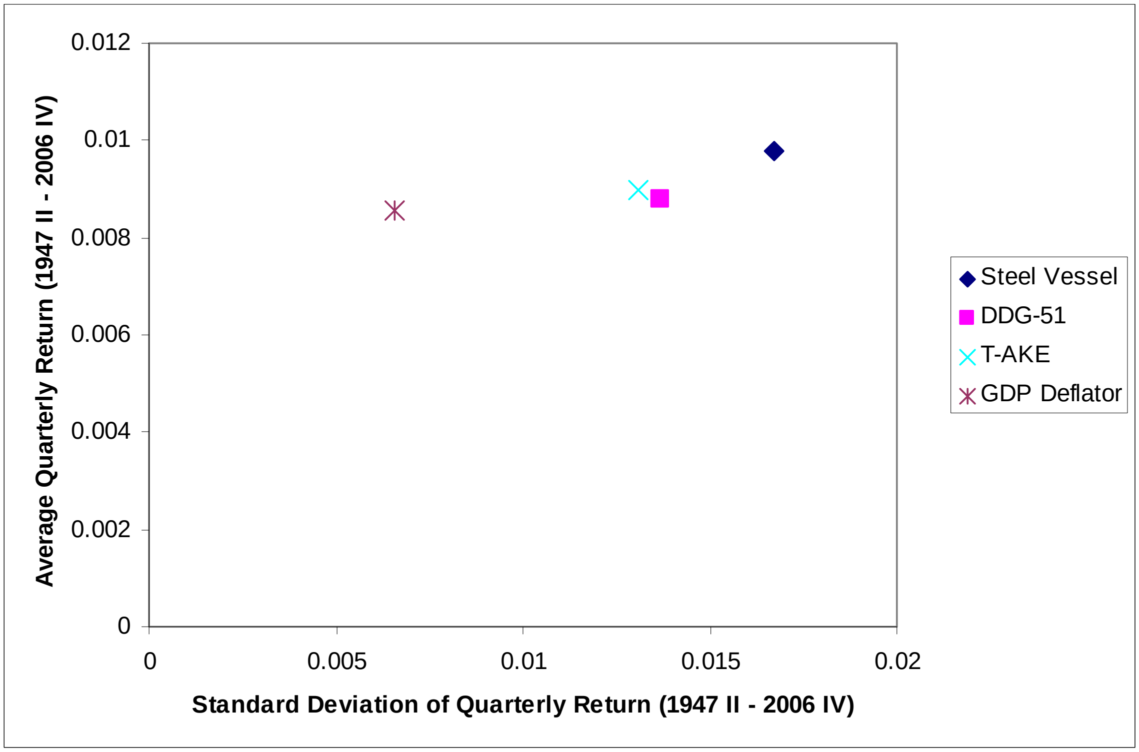

Figure 5. Quarterly Standard Deviation and Average Return of Different Material-cost Indexes

What Figure 5 does not show is how closely correlated any of these indexes is with the actual cost variability a shipbuilder experiences. The best cost index is the one that minimizes a shipbuilder's exogenous risk and, therefore, minimizes the risk premium the Navy must pay the shipbuilder. We know, however, the Steel Vessel Index over-represents iron and steel costs in current naval warship contracts.

The fact the Steel Vessel Index has had a mean quarterly return greater than the other indexes and greater than the economy-wide inflation rate is not prima facie bad news for the Navy. In a competitive setting, a shipbuilder will submit a lower bid up front if it expects super-normal escalation. Therefore, the Navy's expected costs are not, in equilibrium, affected by the Index's mean.

What is more problematic is the known mismatch between the Steel Vessel Index's composition and a shipbuilder's material-cost structure. The shipbuilder bears a risk, for instance, that the prices of iron and steel may tumble while the shipbuilder's do not. A risk-averse shipbuilder will require a premium to bear this mismatch-driven risk.

This mismatch-driven risk could be reduced if the shipbuilder could take a short position on steel futures, i.e., hedge against the risk steel prices will fall. Currently, however, there is no functioning steel futures market.[8]

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[8]There is an ongoing debate as to the feasibility and desirability of a steel futures market. See, for instance, Anderson (2006).

Paradoxically, if the shipbuilder locked in its steel input prices through a long-term, fixed-price contract with a steel mill, the shipbuilder's mismatch-driven risk could be exacerbated, not mitigated. If future steel prices fell, the shipbuilder would receive no advantage on the cost side while receiving reduced revenue from the Navy.

We do not know the "right" material-cost index to use to minimize a shipbuilder's material-cost risk. We do know, however, the Steel Vessel Index is imperfect due to its over-representation of iron and steel. As shown in Figure 5, there is little difference between the DDG-51 and T-AKE approaches; their quarterly returns are positively correlated at the 0.985 level. (By contrast, the Steel Vessel index has a 0.936 correlation with the DDG-51 index and 0.873 with T-AKE.)

Of the three Navy material-cost indexes, T-AKE (0.655) and DDG-51 (0.636) are more highly correlated with the GDP deflator than is the Steel Vessel Index (0.538). The explanation for the Steel Vessel Index's relative lack of correlation with overall inflation in the economy is that the Iron & Steel cost index has a much lower correlation (0.360) with the GDP deflator than the General Purpose Machinery (0.634) and Electrical Machinery (0.609) cost indexes. So, a material-cost index that over-samples Iron & Steel moves away from representation of economy-wide costs.

The foremost argument in favor of the Steel Vessel Index is its familiarity and, consequently, the comfort some shipbuilders have with the Index. Almost everyone we met in the nautical construction industry knows of the Steel Vessel Index, and most have experience with contracts tied to it. The Steel Vessel Index is, perhaps, akin to the Dow Jones Industrial Average in that one would not invent it anew (or at least not with its current weightings), but its fame and tradition keep it in use.[9]

If shipbuilders are familiar and comfortable with the Index, the Navy and the government benefit, as this may imply shipbuilders can be paid less when the Index is in use. The best material-cost index minimizes the exogenous risk shipbuilders perceive they face so as to therefore minimize Navy ship acquisition costs. Unless one believes familiarity is extremely important, however, the manifest cost structure mismatch of the Steel Vessel Index suggests its usage does not minimize the Navy's expected costs.

Conclusions

We do not think the Navy should use the Steel Vessel Index to adjust for material-cost changes in future shipbuilding contracts. The Steel Vessel Index clearly puts excessive weight on Iron & Steel relative to the materials actually used in constructing a modern ship. Usage of the Steel Vessel Index does not appropriately mitigate contractor material-cost risk. Indeed,

[9]Discussing an earlier version of this paper, Jim Jondrow of the Center for Naval Analyses raised the following analogy to the Navy's continued use of the Steel Vessel Index: let us suppose one owned a portfolio that mirrored the NASDAQ Composite Index, but one observed the Dow Jones Industrial Average (or vice versa). On March 10, 2000, the NASDAQ Composite Index closed at an all-time high of 5046, but then fell precipitously, ultimately hitting a bottom of 1114 on October 9, 2002. See "Nasdaq Composite" (n.d.). Meanwhile, the Dow Jones Industrial Average closed at 9929 on March 10, 2000, and at 7286 on October 9, 2002. See Yahoo! Finance (n.d.). The indexes were positively correlated with one another, but the magnitudes of the changes were sharply different.

from a shipbuilder's perspective, a new risk is created: the risk the prices of what the shipbuilder actually buys will rise faster than the price of steel.

The shortcomings of the Steel Vessel Index have been known for many years. The DDG-51 and T-AKE programs created their own material-cost indexes with lower weight on Iron & Steel. Their material-cost indexes, which empirically have been highly correlated with one another, are doubtlessly better indexes than the Steel Vessel Index, though they still appear to put too much weight on Iron & Steel (DDG-51: 20%, T-AKE: 10%).

We urge the Navy to develop a "Modern Vessel Index" that more appropriately represents the material used in constructing ships. Movement toward a better index would also be an opportunity to explore a time-phased material-cost index—e.g., reflect the fact shipbuilders typically buy keel steel early in production, with on-board electronics procured much later in the construction process. The more accurately a material-cost index captures a shipbuilder's external material-cost risk, the less the Navy may expect to pay its shipbuilders.

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Appendix 1. Time-phasing Material- and Labor-cost Indexes

In the examples in the body of this paper, we unrealistically assume all shipbuilder expenses are borne at the end of the three-year build cycle; we then use the material and labor-cost index values at the end of the build cycle to determine the Navy's payment to the shipbuilder.

In fact, actual Navy shipbuilding contracts are more sophisticated. Instead of assuming all costs are incurred at the end of the build cycle, a month-by-month expenditure pattern is assumed, an illustrative example of which is presented in Figure A.1.

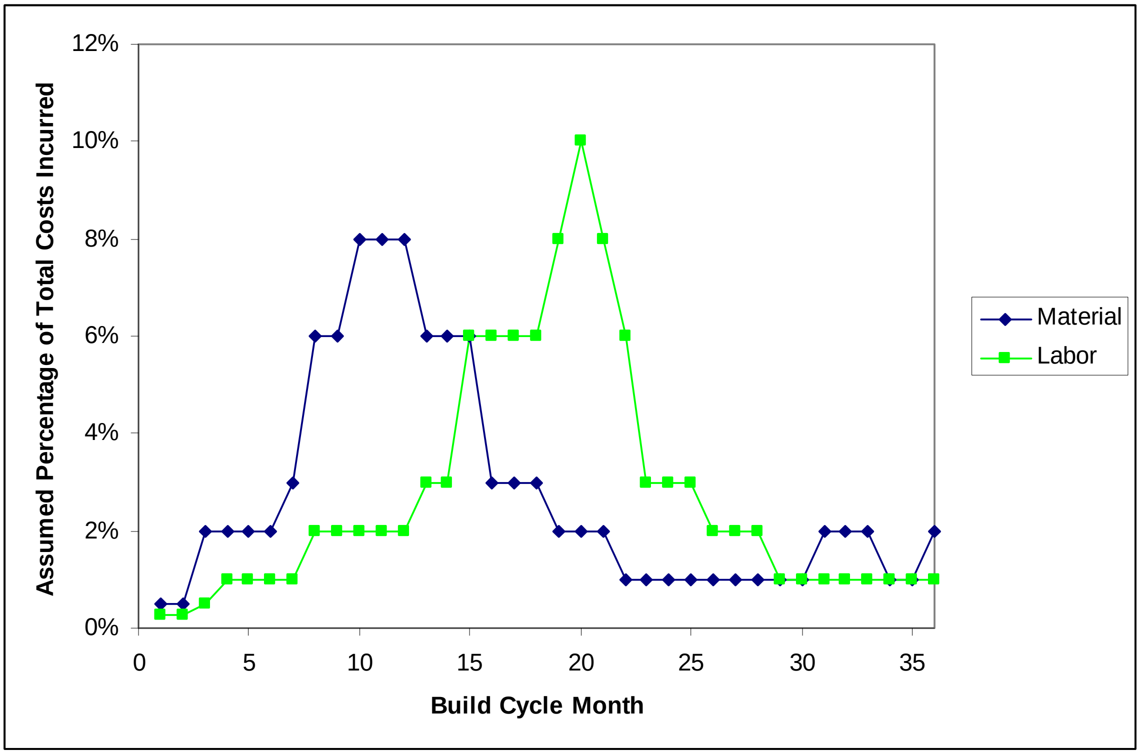

Figure A.1. An Illustration of Assumed Percentages of Total Costs Incurred by Month

Figure A.1, like most Navy shipbuilding contracts, assumes the shipbuilder generally bears material costs (e.g., buying keel steel) in front of labor costs.[10]

The effect of this cost time-phasing assumption is to move forward the implicit median date of contractor expenditure and, therefore, to reduce (assuming the labor and material-cost indexes generally increase) the shipbuilder's inflation-related adjustment. This reduction is generally more marked for material costs because of the standard assumption material costs are borne sooner.

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[10] Standard shipbuilding contracts do not, however, differentiate between types of material. An enhancement we urge the Navy to consider would be to break up material costs, e.g., assume steel expenditures for the keel precede electronics-type expenditures for onboard weapon systems.

Revisiting a Very Simple Example. As above, let us suppose the Navy signs a fixed-price contract for a ship on January 1, 2007, with completion scheduled for January 1, 2010. We assume the ship has $100 million each in expected labor and material costs plus an additional expected or target profit of $20 million. However, labor and material costs are expected to be borne in accord with Figure A.1's pattern.

Let us suppose, during the period 2007-2010, the external labor-cost index designated in the contract goes up 5% while the designated material-cost index goes up 20%. In addition, (though one need not make this pedagogically simplifying assumption) those increases occur uniformly over the 36-month build period. Then the effective increase in assumed labor costs (given Figure A.1's cost incurrence pattern) is 2.6%, while the increase in material costs is 8.1%. Notice the effective increase in labor costs is 52% of the 3-year total increase, while the effective increase in material costs is 40% of the 3-year total increase; this differential reflects the assumption that material costs generally precede labor costs.

In the "Very Simple Example's" contract, the Navy's actual payment to the shipbuilder would be $230.7 million ($102.6 million for labor, $108.1 million for material, $20 million for target profit).

Time-phasing contracts does not axiomatically imply reduced shipbuilder profits (though one might draw such an inference from juxtaposing this example to the body of the paper's "Very Simple Example"). The shipbuilder's initial bid will be made cognizant of how (and whether) labor and material costs are to be indexed. A less generous (but more accurate) indexing approach of this sort will doubtlessly cause the shipbuilder's bid to be greater.

Revisiting a More Realistic Example. In our "More Realistic Example," the Navy provided the shipbuilder with an FPIF contract with a 50/50 sharing ratio on increases or decreases in costs.

As noted above, if the labor-cost index designated in the contract goes up 5% in three years, while the designated material-cost index goes up 20%. The effective increases in the indexes are 2.6% and 8.1%, respectively, adjusting for Figure A.1's assumed expenditure pattern.

In "A More Realistic Example," we had actual labor costs of $105 million. If we scaled this value down in accordance with Figure A.1, the "adjusted" actual labor costs would be $102.6 million. Similarly, "adjusted" actual material costs would be $106.1 million.

The labor compensation adjustment would now be $2.6 million ((0.026 divided by 1.026) multiplied by $102.6 million). The material cost adjustment would be $8.0 million ((0.081 divided by 1.081) multiplied by $106.1 million). The de-escalated base costs of the ship would be $198.1 million (the "adjusted" actual $102.6 million in labor and $106.1 million in material less the compensation adjustments of $2.6 million for labor and $8.0 million for material). The shipbuilder profit would be increased by $0.9 million.

As in the body of the paper, the shipbuilder's profit is greater, holding its actual incurred costs constant, when the material-cost index grows more. The effect of time-phasing is to roughly halve (more of a reduction for material than for labor) the measured indexed inflation rate. But the comparative static result that the shipbuilder is better off when the material-cost index rises more, holding costs constant, remains. Again, such rewards are appropriate if shipbuilder management held costs down better than might have been expected. Conversely, if greater profits were received because an index used to calculate escalation payments is flawed, unwarranted profits may result.

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