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OVERHEAD ALLOCATION AND INCENTIVES FOR COST MINIMIZATION IN DEFENSE PROCUREMENT*

by

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CHAPTER 1

INTRODUCTION

Defense firms typically produce a large number of products. The purpose of this paper is to explain how two features of the current regulatory process create a significant incentive for these multiple-product firms to purposely choose inefficient production methods. Although the magnitude of this incentive appears to be very large, it has not been previously recognized or understood in the procurement literature.

The first feature is that the marginal impact of accounting cost on price varies significantly among products. Prices for a defense firm's products are set according to a rather unique process that combines elements of both competition and cost-based regulation. Defense firms typically produce some purely commercial products and prices for these products are competitively determined. Aside from standard off-the-shelf items such as army boots, the prices of most defense products are nominally cost-based. At the beginning of any procurement the firm is required by law to submit extremely detailed estimates of its anticipated costs of production. The firm is required to certify subject to both criminal and civil penalties that these estimates are "current accurate and complete."[1] The Department of Defense (DoD) devotes a huge amount of resources to auditing the firm's actual costs both to verify the accuracy of previous projections and assess the reasonableness of future projections. The DoD's nominal goal is to pay a price equal to the "true" expected cost. In reality, the negotiated price is likely to be affected by other factors as well. In particular, in cases where closer substitutes exist or where an alternative source might not be prohibitively expensive, the potential cost of these alternatives plays a role. The important consequence of this is that the negotiated price will not necessarily decline or rise by a full dollar when the cost of production declines or rises by a dollar. In more competitive procurements where the cost of alternatives plays a stronger role, changes in projected accounting costs are less important. The typical defense firm is likely to have both well-funded sole source procurements where price is extremely responsive to cost and commercial products or competitive defense procurements where price is much less responsive to cost.

The second feature of the regulatory process concerns the method that defense firms are allowed to use to calculate the cost of each product.[2] The difficulty that almost any multiple-product firm must face is that it is difficult or even impossible to directly assign all costs incurred to individual products. Defense firms have been allowed to deal with this difficulty by adopting the same types of accounting systems as most purely commercial American manufacturing firms have traditionally used. Only a relatively small fraction of costs are directly charged to products. The remaining costs are grouped together into overhead pools and allocated across products usually in proportion to directly charged labor use.

These two features create the following incentive problem. Given the first feature, the firm would typically like to be able to shift costs between products. That is, it would like to be able to assign more of its costs to well-funded sole source procurements instead of to more competitive procurements or commercial products. The second feature provides a method for accomplishing this. Suppose the firms burns a dollar and can claim it was a direct labor expense on a particular contract. The result will be that more overhead is allocated to the contract in question and less is allocated to all other contracts.

A simple example may help clarify the nature of this incentive. Suppose that the firm produces only two products, a defense product and a commercial product. Suppose that the firm incurs $100 of direct labor on each product. Furthermore overhead costs total $300 and are allocated according to direct labor. Therefore the fully allocated cost of each product is $250. The commercial product is sold at a fixed market price independent of any accounting calculations. However, the defense product's price is set to be exactly equal to its accounting cost.

Now suppose that the firm burns $100 and claims it is a direct labor expense for the defense product. The defense product now uses two-thirds of the total direct labor and thus is allocated two-thirds of the overhead. Therefore its fully allocated cost is $400 ($200 of direct labor plus $200 of overhead). As a consequence the price of the defense product rises to $400. In particular, by burning $100 the firm receives increased revenue of $150. The reason for this is that the $100 of direct labor caused $50 of overhead to be shifted onto the defense contract.

Five remarks will now be noted about this incentive effect. First, the potential size of the effect is enormous. It will be shown later in this paper that typical overhead rates and cost-sensitivity differentials actually generate incentives to incur pure waste about as large as described in the example above. By burning $1, a firm might typically generate a return of

$1.20 to $1.50 (i.e., the above example generates a figure on the high side of the plausible range).

Second, the effect is *not* due to cost plus a percentage of cost (CPPC) pricing. CPPC pricing is said to occur when a defense product's price is set equal to its fully allocated accounting cost plus a percentage of this cost. In the example above CPPC pricing was explicitly ruled out. The point of this paper is that the same effect as CPPC pricing occurs through overhead shifting even if there is no CPPC pricing. In fact this effect will be called a "CPPC effect" in this paper. That is, if by spending one dollar the firm receives $(1 + \alpha)$ dollars in revenue, it will be said that there is a CPPC effect equal to $\alpha \times 100$ percent. Thus in the example above, there was a 50 percent CPPC effect.

It is commonly thought that CPPC pricing does occur in defense procurement. The basis for this view is the fact that the price of defense products includes a term labelled as "profit" which tends to be equal to about 10 percent to 15 percent of total price. However in previous work [Rogerson, 1989a] I have argued that most of this term can be interpreted as payments for true economic costs of production which are not formally labelled as costs (facilities capital, working capital, risk-bearing). I conclude that there is perhaps a CPPC effect equal to 2 percent or less arising from the profit calculation. The important point to notice is that the magnitude of the CPPC effect identified by this paper of perhaps 20 percent to 50 percent dwarfs any possible effect occurring from CPPC pricing.

Many analysts of the procurement process have correctly observed that defense firms often seem to behave as though increased costs on defense contracts actually raise their profits. In the absence of any other possible explanation they perhaps quite reasonably have concluded that CPPC pricing must be the source of the problem. The contribution of this paper is to identify another totally separate source of this effect which in all likelihood is much more important.

Third, it is important to note that the firm makes money from *anticipated* cost changes. In this paper the firm can be viewed as truthfully projecting all of its costs to the DoD. It does *not* make money by projecting that costs will be high (in order to get a high price) and then actually having low costs. All of the costs in this paper can be viewed as being fully anticipated by the DoD. To put this another way, the firm actually spends all of the money that is charged as a cost. The profit occurs through shifting the assignment of these costs.

The importance of this point is that auditing is very poorly equipped to deal with this type of behavior. Auditing is relatively good at determining whether the firm actually spent as much as it projected that it would. However, it is relatively poor at determining whether any expenditure which actually occurred was necessary.

Fourth, although the example above was one where the firm wanted to shift overhead from commercial to defense business, the existence of commercial business is not required to generate this effect. The effect will occur whenever the prices of a firm's products exhibit differential sensitivities to cost. Within its defense business such differentials will generally exist. For example, a dollar of increased cost will probably generate nearly a full dollar of increased revenue on a well-funded sole source program or on the follow-on spare parts contracts. However, it may generate much less revenue in a competitive dual sourcing situation or on a contract which many firms are competing for (perhaps because it is the first contract in a long program and the winner of the first contract will be in a sole source position for all follow-on contracts).

Fifth, incentives will be created for more subtle types of cost increases than mere waste. The general incentive for firms will be to increase direct labor usage on products whose revenue is cost-sensitive and decrease direct labor usage on products whose revenue is not cost-sensitive. This can be accomplished by input substitution as well as pure waste. That is, the firm will substitute towards more direct labor on products with cost-sensitive revenues and towards less direct labor on products with cost-insensitive revenues. Two major types of input substitutes exist. The first is capital. Thus we would expect the firm to purposely under-capitalize production of products with cost-sensitive revenues and over-capitalize production of products with cost-insensitive revenues. The second possible input substitute is material. The idea here is slightly more subtle. For many sub-components of a weapon, a firm has the potential option of subcontracting production to another firm or making the component in-house. Subcontracting will result in higher direct material costs for the firm but lower direct labor costs. Thus engaging in more in-house production is essentially a way of substituting towards direct labor and away from direct material. In particular, then, we would expect the firm to purposely engage in too much in-house production for its products with cost-sensitive revenue and too much subcontracting for its products with cost-insensitive revenue. If we translate "cost-sensitive" as "defense products" and "cost-insensitive" as "commercial products" we have the following predictions. Defense firms will purposely under-capitalize their production of defense products and keep too much production in-house. They will also purposely over-capitalize their production of commercial products and keep too little production in-house.

This incentive to distort the input substitution choice is important for a number of reasons. Most importantly, the incentives to increase cost are not confined merely to "padding" direct labor. Almost all of the firm's choices regarding production technologies can be affected. Furthermore both cost-sensitive as well as cost-insensitive products are affected unlike the case of pure waste where "negative" waste is not possible. Finally, auditing is probably even worse at determining whether the optimal input mix has been employed than whether direct labor has been padded.

There is no existing procurement literature which I am aware of which identifies the incentive problem described in this paper. However Braeutigam and Panzar [1989] and Brennan [1990] have made the same general point in the context of models of public utility regulation where the utility has some purely commercial business. They show that, depending upon how costs are allocated, the firm may have an incentive to distort its output and/or input decisions in order to shift overhead to the regulated sector. Although the general point has been made, the formal model of this paper still makes a significant contribution by explicitly analyzing the form that these distortions take in the defense procurement environment. In particular, none of these papers specifically analyze allocation schemes based on direct labor. Thus essentially all of the predictions of this paper regarding the particular sorts of input distortions one would expect to see in defense procurement are new to this paper. Furthermore, on a technical level, the model of this paper is also somewhat different because it considers a multiple product case where products are not necessarily either perfectly competitive or perfectly regulated and the level of competitiveness varies from product to product.

The organization of this paper is as follows. Chapter 2 presents the formal model. Chapter 3 begins the formal analysis by calculating the marginal effect on profit from various input distortions. Chapter 4 then completes the formal analysis by calculating equilibrium input distortions. Chapter 5 attempts to assess the empirical significance of these incentive effects by actually estimating the marginal effect of input distortions on profit for a typical defense firm. Chapter 6 discusses a number of the results in more detail and chapter 7 outlines possible policy approaches. Finally, chapter 8 briefly considers a related incentive issue. Namely, it may be that the overhead allocation process also distorts internal DoD decisions.

CHAPTER 2
THE MODEL

A. Introduction

The model will be presented in two sections. Section B will describe how revenues are determined given the vector of fully allocated costs. Section C will describe how fully allocated costs are determined by the accounting system of the firm.

B. Revenues

Suppose that the firm is producing n products, indexed by $i \in \{1, \ldots, n\}$. Some of these products are sold to the DoD and some may be sold on purely commercial products. For expositional simplicity it will be assumed that a fixed quantity of each product is produced.

Let C_i denote the fully allocated cost of product i.[3] As explained in the introduction, the focus of this paper is on *anticipated* cost changes. Consistent with this, it will be assumed that the DoD knows C_i. The existence of cost uncertainty will be ignored since it is not required to build a model capturing the desired effects. Thus C_i is a certain value. Let r_i denote the revenue from product i. Assume that the revenue from each product is determined by some twice continuously differentiable function,

$$(2.1) \qquad r_i = \phi_i(C_i)$$

where

$$(2.2) \qquad 0 \le \phi_i'(C_i)$$

and

$$(2.3) \qquad \phi_i'(C_i) \le 1 \ .$$

Assumption (2.2) simply requires that revenue be weakly increasing in accounting cost. Assumption (2.3) rules out CPPC pricing. As explained in the introduction, the point of this paper is to show that a CPPC effect exists even when there is no CPPC pricing.

The derivative of revenue with respect to cost, $\phi_i'(C_i)$, is a measure of the cost-sensitivity of the revenue of product i. The basic explanation of why $\phi_i'(C_i)$ varies among products was presented in the introduction in the context of a one-shot fixed price contracting situation. This section will first elaborate on this explanation and then extend it to consider the cases of repeated contracts and cost type contracts.

The basic explanation is that while the regulations nominally require that price be set exactly equal to anticipated cost, in reality, the relative bargaining strength of the two parties also affects price. In particular, cost will become less important in situations where the procurement is more "competitive." Competitive pressures may manifest themselves in many forms. At the most obvious level, there may be multiple firms capable of performing a given contract and the DoD may be able to obtain relatively competitive bids. In other cases, the competition may occur between different weapons systems which could potentially substitute for one another in performing a given mission. Some such substitutions may involve relatively dissimilar systems. For example, increased air-lift capacity may substitute for fast ships in performing the function of transporting military forces. At the extreme case, budget competition may occur between different weapons systems sponsored by different military services which are designed to perform totally different functions. Thus they are substitutes in producing "defense."[4] Finally, competition between defense and non-defense uses of funds can also impact Congress's willingness and thus the DoD's ability to pay for various programs.

In the procurement community the words "competitive/noncompetitive" are typically only applied to discuss the first factor listed above. That is, a contract is spoken of as competitive if many firms can potentially perform it. The words "poorly-funded/well-funded" are typically used to discuss all of the other factors. That is, a program is spoken of as well-funded if it can succeed in attracting a large budget in competition with other defense programs and/or nondefense programs. This is a fairly natural way of thinking about the competitive forces at work. It captures the fact that all factors but the first involve interprogram competition and thus manifest themselves through the responsiveness of the program budget to cost increases. The first factor involves intraprogram competition and thus is not related to the responsiveness of the program budget. This paper will use the term "competition" to refer to both types of competition. The term "sole source" ("multiple source") will often be used to describe a program for which there is a small (large) amount of intraprogram competition. The term "well-funded" ("poorly-funded") will often be used to describe a program for which there is a small (large) amount of interprogram competition. In terms of this typology a contract's revenues are cost-sensitive if it is sole source and well-funded.

One can summarize the basic explanation described above as follows. When a firm is negotiating the price for a sole source well-funded contract there is little else but the cost-based pricing regulations to control the size of revenues. In particular then, if the costs of production go up by one dollar, the revenues the firm receives are also likely to go up by one dollar. However, when a number of firms are competing for a given contract or the contract is not well-funded, these factors may play a significant role in controlling price regardless of the cost-based pricing regulations. To the extent this is true, cost increases are not as likely to be reflected in revenue increases.

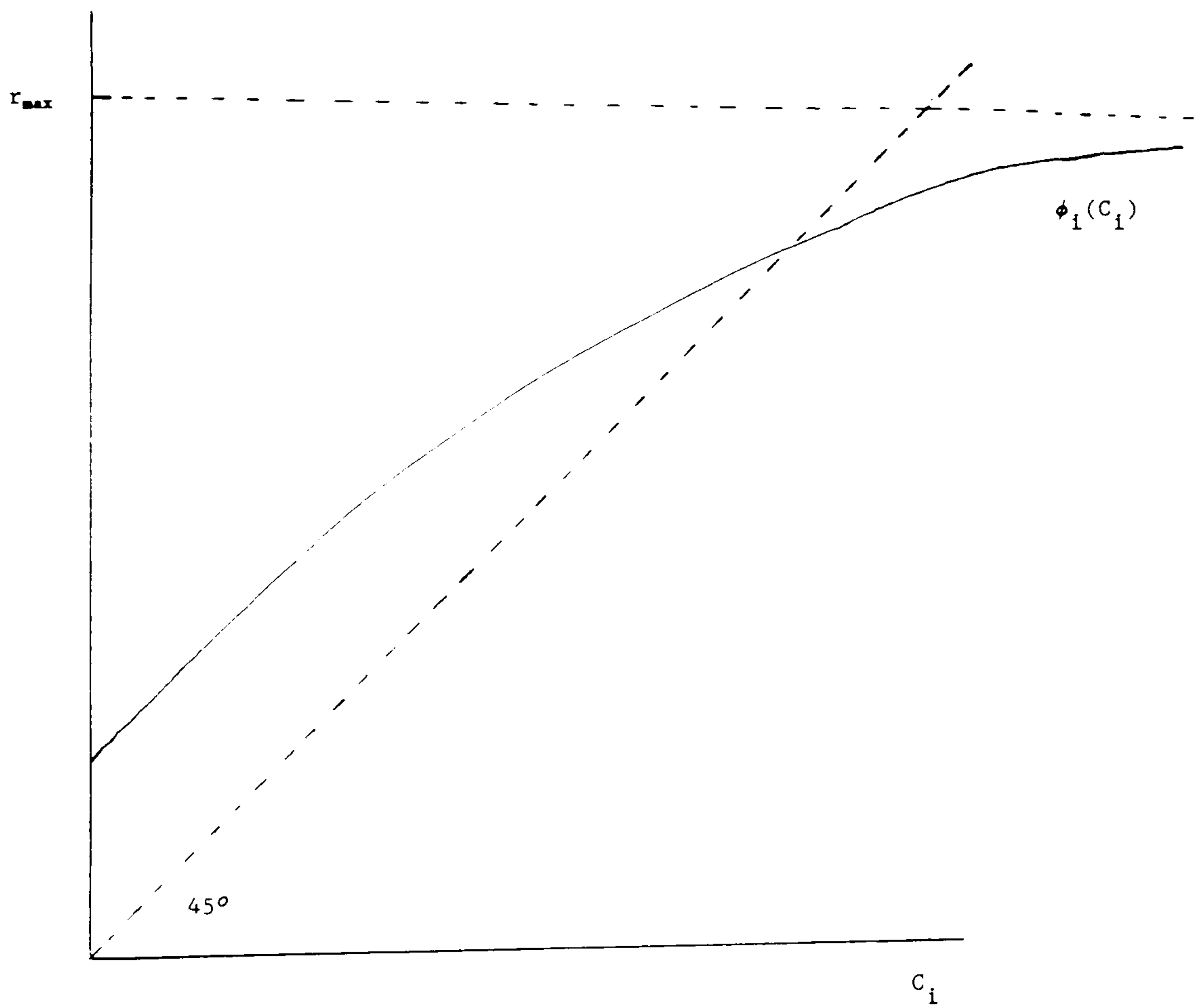
It should be noted that cost-sensitivity is a local concept. That is, the cost-sensitivity of a product's revenue is likely to change as its costs change. In particular, it is likely that almost all defense products have a revenue function similar to that drawn in figure 2.1 if large enough ranges of possible costs are considered. For extremely low costs competitive pressures will be small and revenues will rise on a dollar-for-dollar basis with cost. However as costs rise, both intraprogram and interprogram competitive forces will become more important. There is probably some maximum price, r_{max}, that the DoD would be willing to pay for any product. Thus eventually the revenue function must become nearly constant as it asymptotes to this maximum level.

Therefore comparisons of the cost-sensitivity of the revenue functions of two products can only be made given a level of cost for both products. In particular, note that it is not natural to try and rank the cost-sensitivity of the revenues of products by globally comparing the slopes of revenue functions. The revenues of product i would certainly be less sensitive to costs than those of product j if the following were true.

$$(2.4) \qquad \underset{C_i \geq 0}{\text{maximum}}\ \phi_i'(C_i) \leq \underset{C_j \geq 0}{\text{minimum}}\ \phi_j'(C_j)$$

Figure 2.1

The Revenue Function



However such rankings in general will not be possible because the slope of all revenue functions will be zero for high enough costs. (Thus the only case where (2.4) would be true would be where product i was sold on a perfectly competitive market and $\phi_i'(C_i)$ was identically equal to zero.) Therefore the concept of cost-sensitivity has to be viewed as a more local property that can only be discussed given a specified range of costs. For example it may be that

(2.5) $$\phi_i'(C_i) < \phi_j'(C_j)$$

for particular cost values C_i and C_j. Then at these costs the revenues of product i are less cost-sensitive than the revenues of product j. Usually in the text it will be clear at which cost vector the comparison is being made. When more general statements to the effect that revenues of one product are more cost-sensitive than revenues of another product are made, this should be interpreted as meaning that the slopes exhibit the desired rankings over a broad range of plausible cost outcomes.

Finally one expositional point about the concept of cost-sensitivity should be noted. Strictly speaking, cost-sensitivity is a property of the *revenue function* of a product and not of a product. However to smooth and speed the exposition the phrase "the revenue function of product i" will simply be shortened to "product i" when discussing cost sensitivity. For example, the situation in (2.5) will be described as one where product i is less cost-sensitive than product j.

This completes the general interpretation of the model in the context of a one-shot fixed price contract setting. It will now be shown that the model is actually extremely general and can be interpreted as also applying to cost type contracts and as capturing some phenomena that occur because of the existence of repeated contracts.

First consider the issue of repeated contracts. In the one-shot interpretation given above, one had to assume that all cost changes were perfectly anticipated by the DoD. As explained in the introduction, this assumption is not that unreasonable given the resources the DoD devotes to auditing. In reality, of course, not all cost changes can be perfectly anticipated by the DoD. However it is also the case in reality that the DoD will be able to discover cost changes with a lag and then use this information in all future negotiations. This phenomena is of particular importance in the (fairly typical) situation where the firm is repeatedly producing annual lots of the same weapon system.

The model of this section can also be interpreted as applying to this more general case. Suppose that the DoD discovers some cost changes only with a lag and then uses the information about cost changes in all future negotiations. This type of model is common in the Soviet incentives and regulation literature and is often labelled the "ratchet effect" or "regulatory lag."[5] The basic idea captured by such a model is that any cost change will leave immediate revenues unaffected but will affect longer run revenues when the change is discovered. In this context, the above model can be interpreted as one where a firm is considering the present discounted value of costs and revenues from a product over a number of future years. That is, $C_i(r_i)$ is the present discounted value of costs (revenues) over the future time horizon being considered. Even if revenues are eventually reduced by the full amount of any cost reduction, the presence of a lag will mean that the present discounted value of revenues over the entire time horizon will not be reduced by the full amount. Thus the existence of regulatory lag yields the result that the slope of revenues as a function of actual costs is less than one.

In particular, therefore, the fact that the DoD is able to anticipate some cost changes instantaneously and others only with a lag is consistent with the basic model of this section that actual costs affect revenues but possibly not at a dollar-for-dollar rate. We can interpret a smaller effect as occurring when more costs changes are determined with a lag and/or the lag grows longer.

Now consider the issue of cost type contracts. All of the discussion above has been cast as though all contracts were fixed price. However, this was simply for expositional convenience. Given the focus of this paper on *anticipated* cost changes, the distinction between fixed price and cost reimbursement contracts is not that important since cost-sharing arrangements simply determine how *unanticipated* cost changes affect revenue. Therefore the modelling assumption that revenues are a function of accounting costs as captured in (2.1)-(2.3) is also appropriate to describe the situation occurring under cost type contracts. However the interpretation of this assumption may be slightly different and this may in turn influence one's priors as to the likely shape of the function. This will now be described. For expositional simplicity the case of a cost plus fixed fee contract where government pays for 100 percent of all cost overruns will be discussed.

A reasonable initial reaction to the case of cost type contracts would be to argue that revenues move on a dollar-for-dollar basis with costs--i.e., i.e., in terms of the formal models, $\phi_i'(C_i)=1$. After all, the contract explicitly requires that *ex post* revenues move on a dollar-for-dollar basis with *ex post* accounting costs. Furthermore, note that the presence of regulatory lag will not weaken this relationship since the contract adjusts revenues on the current contract to reflect costs of the current contract. Thus even if regulatory lag has caused the relationship between revenues and costs to be somewhat attenuated for fixed price contracts, cost type contracts should be unaffected.

The flaw with this argument is that it ignores the role of funding limitations on the firm's revenues. A cost type contract is not a license to spend potentially infinite amounts of money on a given task and be reimbursed for all expenditures. A cost type contract includes a clause specifying the maximum amount of costs the firm can incur and be reimbursed for. Expenditures above this level require explicit permission from the contract officer. Obtaining permission is by no means assured or easy since the contract officer cannot allow extra expenditures unless he can first obtain an appropriation of more funds from higher authorities.

Thus cost increases up to the ceiling level probably can be correctly viewed as generating dollar-for-dollar increases in revenues. However reimbursement for cost increases above the ceiling depends on the outcome of negotiations between the DoD and the firm. The firm of course has the option of ceasing expenditures if no more funds are forthcoming. However either because of reputational concerns or because completion of the current contract will open the door to related future contracts, defense firms will often complete cost type contracts regardless of the level of funding. In fact, many people have argued that defense firms as a standard operating procedure lose money on cost type R&D contracts in the early stages of a program in order to be selected as the sole producer of the weapon and (hopefully) earn large profits when negotiating fixed price production contracts in a sole source environment. The economic rationale for this situation is discussed in Rogerson [1989b] and will not be discussed here. For the purposes of this paper, the important fact to note is simply that, in many cases, it may well be the case that defense firms purposely accept cost type contracts which are not funded (and will not be funded) up to the level of the expenditures they truly expect to incur. In these cases, the marginal effect of cost changes on revenues may well be less than one, and perhaps even equal to zero. This is because *ex ante* negotiations over the ceiling level and *ex post* negotiations over incremental funding for overruns will in fact determine the firm's revenues.

In summary then, the general theoretical construct that revenues depend on cost applies to products procured under both fixed price and cost type contracts. The absence of any regulatory lag with cost type contracts suggests that revenues may be more responsive to costs on cost type contracts than fixed price type contracts. However, competition for cost type contracts can often be quite intense and the result may be that firms often purposely accept underfunded contracts. This is especially true for R&D contracts in the early phases of a major new program. In such cases, revenues might well be quite unresponsive to cost. Thus it is by no means clear that revenues will in general be more responsive to costs on cost type contracts.

C. Fully Allocated Costs

This section will formally model the cost-accounting system that the firm will be assumed to use. To clearly illustrate the effects in the simplest possible model it will be assumed that all overhead is allocated in proportion to direct labor usage. To the extent that overhead is allocated according to direct labor the effects identified in this paper will continue to exist in more complex environments with multiple overhead pools and where not all overhead is necessarily allocated according to direct labor.

The cost accounting system directly assigns some labor and material to individual contracts. Let L_i and M_i denote, respectively, the dollar value of direct labor and direct material for contract i. All other inputs are called indirect cost or overhead. Let V denote the total dollar value of overhead. Assume that some of the overhead costs are in fact incurred for one and only one product. They are not directly assigned to contracts because it would be expensive or perhaps impossible to objectively do so. Let Z_i denote the costs for product i which are included in overhead. Finally, let J denote joint costs which cannot be assigned to any particular contract, even in principle. Total overhead is the sum of these components.

(2.6) $$V = \sum_{i=1}^{n} Z_i + J$$

Overhead is allocated to contracts according to direct labor usage. Thus the overhead allocated to product i, denoted by V_i, is given by

(2.7) $$V_i = \frac{L_i V}{\left[\sum_{k=1}^{n} L_k\right]}$$

Let R^M denote the overhead rate which is the ratio of overhead to direct labor.

(2.8) $$R^M = \frac{V}{\sum_{k=1}^{n} L_k}$$

We can view each dollar of direct labor as attracting R^M dollars of overhead. Consistent with intuition, (2.7) can be rewritten as

(2.9) $$V_i = R^M L_i .$$

The total cost of product i, denoted by C_i, is the sum of all direct and indirect costs. It is given by

(2.10) $$C_i = (1 + R^M) L_i + M_i$$

or, equivalently, by

(2.11) $$C_i = L_i + M_i + \left(\frac{L_i}{\sum_{k=1}^{n} L_k} \right) \left(\sum_{k=1}^{n} Z_k + J \right) .$$

Finally, it will be useful to let a variable without the subscript "i" denote the vector of corresponding variables for each product--i.e.,

(2.12) $$C = (C_1, \ldots, C_n)$$

(2.13) $$L = (L_1, \ldots, L_n)$$

etc.

CHAPTER 3

FORMAL ANALYSIS: THE MARGINAL EFFECT OF INPUT CHOICE ON PROFIT

A. Introduction

Both chapters 3 and 4 will view the values of the cost pools (i.e., L, M, Z, and J) as choice variables for the firm. Both the case where the firm can simply incur waste and the case where the firm substitutes between inputs will be considered. The firm's revenues for product i are determined by the function $\phi_i(C_i)$ as described in section 2B where C_i is determined as described in section 2C. Therefore the firm's profits given its input choices are described by the function

$$(3.1) \qquad \Gamma(L,M,Z,J) = \sum_{j=1}^{n} \phi_j'(C_j) - C_j$$

where C_j is determined by (2.11).

Chapter 4 will actually solve for the profit maximizing input choices of the firm. This section will perform a more basic calculation. It will calculate the marginal effect on profit from various types of waste or input substitutions. This is useful for a number of reasons. First, it will provide an extremely clear and simple explanation of the cause and nature of the incentive effects acting on the firm. Second, the formulas developed here will provide a useful method for calculating the magnitude of the incentive effects which actually exist. This will be done in chapter 5.

Section B will present the fundamental theoretical result. Then sections C-G will apply it to the various cases of interest.

B. The Fundamental Result

It will be useful to first define one more piece of notation. Let A denote the weighted average cost-sensitivity of all the firm's contracts where the weights equal the share of direct labor used by each contract.

$$A = \sum_{j=1}^{n} \phi_j'(C_j)L_j/\left(\sum_{k=1}^{n} L_k\right) \tag{3.2}$$

Just as for R^M and C_i, A will be viewed a function of the input choices, L, M, Z, and J. However for expositional convenience this functional dependence will not be explicitly indicated in the notation.

Proposition 1 now will present the derivative of profit with respect to the variables L_i, M_i, Z_i, and J. This is the basic technical result that will be used in subsequent sections. Since the proofs simply involve straightforward differentiation of (3.1), they will not be presented.

Proposition 1:

$$\frac{\partial\Gamma}{\partial M_i} = \phi_i'(C_i) - 1 \tag{3.3}$$

$$\frac{\partial\Gamma}{\partial Z_i} = A - 1 \tag{3.4}$$

$$\frac{\partial\Gamma}{\partial J} = A - 1 \tag{3.5}$$

$$\frac{\partial\Gamma}{\partial L_i} = R^M[\phi_i'(C_i) - A] + [\phi_i'(C_i) - 1] \tag{3.6}$$

Extremely intuitive explanations exist for all four formulas. First consider (3.3). The only effect of increasing direct material by one dollar is that the cost of contract i goes up by one dollar. Revenues rise by $\phi_i'(C_i)$. The effect on profit is the change in revenues minus the change in cost which is given by (3.3). Now consider (3.4) and (3.5) together. Suppose that overhead increases by one dollar. (Whether it is Z_i or J is irrelevant since both are allocated in the same fashion.) The change in profit then equals the change in revenues minus one dollar (since one dollar is the change in cost). The change in revenue will now be calculated. The increased dollar of overhead is allocated to all contracts in proportion to direct labor cost. Therefore contract i experiences a change in cost of

$$(3.7) \qquad \frac{L_i}{\sum_{k=1}^{n} L_k}$$

dollars. Therefore revenue on contract i goes up by

$$(3.8) \qquad \frac{L_i}{\sum_{k=1}^{n} L_k} \phi_i'(C_i)$$

dollars. The total revenue change is the sum over i of the terms in (3.8). This by definition is A, the weighted average cost-sensitivity. Therefore, in summary, a dollar increase in overhead causes revenues to increase by A dollars. The change in profit thus equals A-1 dollars which is (3.4) and (3.5).

Expression (3.6) is more complicated. However the insights necessary to explain this have essentially been developed above. When direct labor on contract i increases by one dollar there are two effects. The first effect is that the cost of contract i goes up by one dollar because all of the dollar increase is directly assigned to contract i. Just as for (3.3), this causes a profit change of

$$(3.9) \qquad \phi_i'(C_i) - 1$$

which is the second term of (3.6). The second effect is that the extra dollar of direct labor attracts R^M dollars of overhead to contract i. Suppose that one dollar of overhead is shifted to contract i. This means that one dollar of overhead is taken away from all contracts. By the analysis of (3.4) and (3.5) this causes revenue to decline by A dollars. Since the dollar of overhead is now assigned to contract i, revenues increase by $\phi_i'(C_i)$. Therefore the net change in revenue when one dollar of overhead is shifted to contract i is

$$(3.10) \qquad \phi_i'(C_i) - A.$$

However the dollar of direct labor attracts R^M dollars of overhead. Thus profit changes by

$$(3.11) \qquad R^M [\phi_i'(C_i) - A] .$$

This is the first term of (3.6).

C. Pure Waste

Suppose that the firm could burn a dollar and have it be labelled as either a direct labor expense or direct material expense on contract i or as an overhead expense. Would it want to do this and why? This is the question addressed by this section.

First consider the question of direct material or overhead waste. The firm will never have an incentive to engage in this type of waste. This is because revenues are assumed to increase by at most one dollar when costs go up by one dollar. Thus the best result that could possibly occur is that the firm's profits would be unchanged. In general, of course, revenues will go up by less than one dollar and therefore profits will actually decline. In conclusion, the assumption that there is no CPPC pricing (i.e., $\phi_i'(C_i) \leq 1$ for every i) means that the firm has no incentive to incur pure waste of overhead or any direct input which is not an allocation base.

Now the more interesting question of direct labor will be turned to. Just as for direct material, the dollar of direct labor will only be partially reimbursed through revenues and the decrease in profits is given by

$$(3.12) \qquad \phi_i'(C_i) - 1 \quad .$$

However now there is an extra effect due to overhead shifting. In particular, if contract i is more cost-sensitive than the weighted average of the firm's contracts, then the firm can increase its revenues by shifting overhead to contract i where it will be more fully reimbursed. If this effect is big enough it may overwhelm the other effect and the firm will find it profitable to incur pure waste of direct labor for contract i.

Three factors determine the magnitude of this effect. These are $\phi_i'(C_i)$, R^M, *and* $[\phi_i'(C_i) - A]$. Each of these will be discussed in turn. First consider $\phi_i'(C_i)$, the cost-sensitivity of contract i. As contract i becomes more cost-sensitive, the penalty to incurring a dollar of waste grows smaller because a larger fraction of it will be reimbursed. For a perfectly cost-sensitive contract there is no penalty at all.

Now consider the overhead rate, R^M. The overhead shifting effect is larger if R^M is larger because one dollar of direct labor attracts more overhead. In particular then, the incentive to incur direct waste on contracts of above average cost-sensitivity grows larger as the overhead rate grows larger.

Finally, consider the differential cost-sensitivity between contract i and the average contract, $\phi_i'(C_i) - A$. This term must be positive in order for the firm to want to shift overhead to contract i. As it becomes more positive, the incentive to shift overhead through incurring direct labor waste grows larger. This is because contract i will reimburse relatively more of the overhead than would have occurred if the overhead had been allocated to all contracts.

D. Input Substitution: General

The general idea illustrated by the calculations of section C is that the firm would like to increase direct labor usage on cost-sensitive contracts and decrease direct labor usage on cost-insensitive contracts in order to shift overhead towards contracts that will reimburse a greater share of it. Incurring pure waste labelled as direct labor is one method to accomplish this. However substituting between direct labor and some other input is obviously another way to do so. Section D will develop the general formula for calculating the impact on profit from substitutions between labor and any combination of other inputs. Then sections E-G will consider particular substitution problems using the general formula derived in section D.

The general input substitution problem will now be described. It will be assumed that the firm can substitute between L_i, M_i, and Z_i. View L_i as the firm's choice variable. Then assume that the required amounts of the other two inputs are given by the two differentiable functions

$$Z_i = g_i(L_i) \tag{3.13}$$

and

$$M_i = h_i(L_i) \quad . \tag{3.14}$$

Let $\pi(L)$ denote the firm's profits given its choice of labor inputs and given the resulting choice of Z and M required by (3.13) and (3.14). (View J as fixed at some level for this entire analysis.) Formally, the function $\pi(L)$ is given by (3.1) where Z_i and M_i are determined by (3.13) and (3.14).

Proposition 2 presents the marginal effect on profit of a change in direct labor (with adjustment of other inputs).

Proposition 2:

$$\frac{\partial \pi}{\partial L_i} = \left[R^M - g_i'(L_i)\right]\left[\phi_i'(C_i) - A\right] + \left[1 + h_i'(L_i) + g_i'(L_i)\right]\left[\phi_i'(C_i) - 1\right] \tag{3.15}$$

<u>Proof</u>:

By the chain rule,

$$\frac{\partial \pi}{\partial L_i} = \frac{\partial \Gamma}{\partial L_i} + h_i'(L_i)\frac{\partial \Gamma}{\partial M_i} + g_i'(L_i)\frac{\partial \Gamma}{\partial Z_i} \quad . \tag{3.16}$$

The result now follows immediately by substituting in the results from Proposition 1.

QED

The calculation of (3.15) is a relatively trivial application of Proposition 1 as explained in the proof. An increase in L_i of one dollar causes M_i to change by $h_i'(L_i)$ dollars and Z_i to change by $g_i'(L_i)$ dollars. The impact of each of these three effects can be calculated from Proposition 1. Then $\partial\pi/\partial L_i$ is simply the sum of these three effects.

Expression (3.15) will not be further explained in general. Further analysis will be conducted in the context of more specific types of input substitution problems in sections E-G. However, before doing this, one general methodological point applying to all of these analyses will be made.

In general when the firm substitutes between labor and other inputs there are two factors affecting its profits. The first factor is simply cost efficiency. That is, all other things being equal, if spending one dollar on labor will save ten dollars of some other input, the firm will be inclined to do this. The second factor is the effect of the input substitution on cost allocation which in turn affects profits.

The goal of sections E-G is to analyze the nature of the incentives operating on the firm due to the second factor. Formally, the way to isolate this second factor is to assume that the firm is currently making an optimal input choice from the standpoint of cost minimization and to then measure the marginal effect of increased labor usage (with a corresponding decrease in other input usage) on profit. To put this another way, the upcoming sections will measure the marginal effect on profit of using one more dollar of direct labor when this causes one dollar less of other inputs to be used. Thus there is no cost efficiency effect and the entire change in profit must be due to cost allocation effects.

E. Labor-Material Substitution

In this section it will be assumed that

$$g_i'(L_i) = 0 \tag{3.17}$$

for every L_i. Thus only substitution between labor and material is considered. As explained above it will also be assumed that one dollar of increased labor generates one dollar of decreased material in order to focus on cost allocation effects. Formally, this is given by the assumption that

$$h_i'(L_i) = -1 \tag{3.18}$$

at the value of L_i for which the derivative is being evaluated.

Substitution of (3.17) and (3.18) into (3.15) yields

$$\frac{\partial \pi}{\partial L_i} = R^M[\phi_i'(C_i) - A] \ . \tag{3.19}$$

Recall that (3.6) gives the marginal effect on profit of a dollar of pure labor waste. A comparison of (3.6) and (3.19) reveals that (3.19) equals the first term of (3.6). The reason for this is straightforward. Just as for the pure waste case, spending an additional dollar on direct labor causes R^M dollars of overhead to shift to contract i. However this is now the only effect. This is because the increased dollar of direct labor expenditure is coupled with a decreased dollar of direct material expenditure. Thus there is no change in direct cost.

Therefore the firm will in general have the incentive to distort direct labor usage on *all* of its contracts, the only exception being contracts which are of precisely average cost sensitivity. It will want to use too much labor on contracts which are of above average cost-sensitivity and use too little direct labor or contracts which are of below average cost-sensitivity. Its incentives to do this will be greater if the overhead rate is greater and if the variation in cost-sensitivity among contracts is greater.

One final comment about the comparison between this case and the pure waste case should be noted. Expression (3.19) is always greater than or equal to (3.6). This is for the obvious reason. Profits in general rise if direct material usage decreases. Therefore using a dollar of productive labor to replace a dollar of material is more profitable than simply burning the dollar.

This general principle will apply to almost all input substitution cases. It will generally always be more profitable to increase direct labor in such a way that other inputs can be reduced rather than to simply burn money and call it direct labor. This suggests that the firm will never have the incentive to engage in pure waste in situations where input substitution is possible and this formal result will be demonstrated in section 4.

However the pure waste model is still interesting for two reasons. First, over short enough time horizons, changing technologies in order to effect an input substitution may be difficult. Thus pure waste may still be an important short run phenomena. Second, the pure waste model very clearly illustrates the basic incentive structure created by overhead allocation based on direct input usage and it is thus of analytic value.

F. Labor-Overhead Substitution

In this section it will be assumed that

$$h_i'(L_i) = 0 \tag{3.20}$$

for every L_i. Thus only substitution between overhead and labor will be considered. As explained above it will also be assumed that one dollar of increased labor generates one dollar of decreased overhead in order to focus on cost allocation effects. Formally, this is given by the assumption that

$$g_i'(L_i) = -1 \tag{3.21}$$

at the value of L_i for which the derivative is being evaluated.

Substitution of (3.20) and (3.21) into (3.15) yields

$$\frac{\partial \pi}{\partial L_i} = (1+R^M)\ [\phi_i'(C_i) - A]\ . \tag{3.22}$$

A comparison of (3.19) and (3.22) reveals that the term "R^M" in (3.19) has been replaced by the term "$1 + R^M$" in (3.22). The reason for this is very simple. When the firm spends one more dollar on L_i and one less dollar on Z_i it is directly transferring one dollar of overhead to contract i. This occurs in addition to the fact that the dollar of direct labor attracts R^M dollars of overhead. For the labor-material substitution case only R^M dollars of overhead are transferred. For the labor-overhead substitution case, $1 + R^M$ dollars are transferred.

The formulas for the labor-material case and labor-overhead case are very similar and all the comments made for the labor-material case therefore apply here as well. They will not be repeated. However some new points focusing on the difference between the formulas will be made.

It will be useful to label each of the two incentive effects described above. Rewrite (3.22) as

$$(3.23) \qquad \frac{\partial \pi}{\partial L_i} = R^M[\phi_i'(C_i) - A] + [\phi_i'(C_i) - A]$$

The first term of (3.23) corresponds to the incentive effect identified for the pure waste and labor-material substitution cases. It will be called the "allocation base" incentive to distort labor choice. The reason for this name is that the incentive to distort direct labor occurs because it is the allocation base for overhead. The second term of (3.23) corresponds to the extra incentive that only applies to the labor-overhead case. It will be called the "direct" incentive to distort labor choice. The reason for this name is that the incentive to distort direct labor occurs because the substitution directly shifts costs between overhead and contract i.

Three points should be noted about the direct incentive to distort labor choice. First, the incentive to distort the labor-overhead choice will be greater than that to distort the labor-material choice because of this extra effect. In fact it will be argued in chapter 5 that a typical value for R^M is approximately 1. Thus the incentive to distort the labor-overhead choice might typically be approximately twice as large as that to distort the labor-material choice.

Second, the direct incentive affects all of the firm's direct inputs and not only those used as an allocation base. In particular, in this paper's model, the firm would also have an incentive to distort the material-overhead choice in the same fashion as the labor-overhead choice.

Third, different policy approaches might be required to deal with this extra effect. In particular, even if overhead were allocated according to some totally non-manipulable criterion (e.g., an equal share to each contract), the direct incentive effect would still exist.

G. Subcontracting

As explained in the introduction, the choice of the level of subcontracting can be viewed as an input substitution choice. Increasing the level of in-house production clearly increases direct labor, L_i, and decreases material, M_i. If these were the only two effects then the analysis of part E would apply. However there is likely to be a third effect which occurs as well which complicates the analysis. This is that the use of some inputs classified as overhead will also likely increase. Formally this means that Z_i will increase.

Formally, then, view L_i as the choice variable of the firm. Higher values of L_i correspond to increased levels of in-house production--i.e., decreased levels of subcontracting. Consistent with the description in the above paragraph, assume that

(3.24) $$g_i'(L_i) > 0$$

and

(3.25) $$h_i'(L_i) < 0$$

for every L_i. As usual, in order to focus on cost allocation affects, it will be assumed that one dollar of increased labor use generates a net decrease of one dollar of other input use. Formally this is given by the assumption that

$$(3.26) \qquad h_i'(L_i) + g_i'(L_i) = -1 .$$

Substitution of (3.26) into (3.15) yields

$$(3.27) \qquad \frac{\partial \pi}{\partial Li} = [R^M - g_i'(L_i)]\ [\phi_i'(C_i) - A] .$$

Formula (3.27) cannot in general be signed. This is because $g_i'(L_i)$ is positive by assumption. Thus the term $R^M - g_i'(L_i)$ may in general be positive or negative. This indeterminacy is due to the fact that there are two opposing effects at work. When in-house production increases, direct material usage goes down. This input usage is shifted into usage of the other two inputs and this creates the two opposing effects. To the extent that material cost is shifted to direct labor cost, there is the standard allocation base effect. Therefore *more* cost is allocated to contract i. To the extent that direct material is shifted to overhead, *less* cost is allocated to contract i. Thus the first effect causes R^M dollars to be shifted towards contract i; the second effect causes $g_i'(L_i)$ dollars to be shifted away from contract i. The net result is that $[R^M - g_i'(L_i)]$ dollars are shifted towards contract i.

Therefore, in general, the nature of the distortion in the level of subcontracting is indeterminate. If

$$(3.28) \qquad R^M - g_i'(L_i) > 0 ,$$

then the same qualitative result as was found in all previous sections will hold. Namely the firm will have the incentive to use too much (too little) direct labor on contracts which are of above average (below average) cost-sensitivity. This translates into the firm having the incentive to do too little (too much) subcontracting on contracts which are of above average (below average) cost-sensitivity. However if

(3.29) $$R^{M} - g_{i}'(L_{i}) < 0$$

then exactly the opposite qualitative result will hold.

The ability to develop a precise prediction from this model therefore depends upon whether it can be argued that the term

(3.30) $$R^{M} - g_{i}'(L_{i})$$

will, in general, be either always positive or always negative. Fortunately such a conclusion appears possible. In particular, it will be argued below that (3.30) should, in general, be positive for typical defense firms. Therefore the same qualitative predictions regarding the nature of the direct labor choice found in previous sections seem likely to hold.

The reason that (3.30) is likely to be positive will now be explained. View the overhead rate as a function of direct labor.

(3.31) $$R^{M} = \frac{\sum_{j=1}^{n} g_{j}(L_{j}) + J}{\sum_{j=1}^{n} L_{j}}$$

Then the derivative of the overhead rate with respect to L_i is given by

$$(3.32) \qquad \frac{\partial R^M}{\partial L_i} = \frac{g_i'(L_i) - R^M}{\sum_{j=1}^{n} L_j}$$

In particular then, (3.30) is positive if and only if $\partial R^M/\partial L_i$ is negative.[6]

It is a well-accepted stylized fact in defense procurement circles that $\partial R/\partial L_i$ is negative. That is, if the firm accepts more business and thus employs more direct labor, its overhead rate will be lower. Defense analysts typically speak of L_i as a measure of the "business base" and describe the result as being that "the overhead rate is a declining function of the business base."[7] The reason typically given for this is the existence of "fixed costs" in the overhead pool which should be thought of as representing economies of scale and/or scope. The result is that while direct labor goes up proportionately with the "amount" of business, a variety of overhead costs do not. This implies that overhead rates decline as direct labor usage increases. Therefore it seems likely that the typical defense firm is in a situation where its overall overhead rate would decline if it brought more production in-house.

This part will conclude with a simple example illustrating this "fixed costs" view of overhead. Suppose that each g_i function is given by

$$(3.33) \qquad g_i(L_i) = a + bL_i \ .$$

Thus a is the fixed component of product i's overhead costs. Total overhead is then given by

$$(3.34) \qquad V = J + na + (nb)\left[\sum_{j=1}^{n} L_j\right] .$$

The total fixed component of overhead equals the joint cost plus the n individual fixed components. Denote it by F.

$$F = J + na \tag{3.35}$$

Let θ denote the share of total overhead which is fixed.

$$\theta = \frac{F}{V} \tag{3.36}$$

It is straightforward to show that

$$R^{M} - g_i'(L_i) = \theta R^{M} \; . \tag{3.37}$$

Substitution of (3.37) into (3.27) yields

$$\frac{\partial \pi}{\partial L_i} = \theta R^{M} \left[\phi_i'(C_i) - A \right] \; . \tag{3.38}$$

A comparison of (3.38) and (3.19) reveals that the marginal effect on profit for the subcontracting case equals θ times the effect for the labor-material substitution case. This is intuitively reasonable. Increased labor use due to increased in-house production is essentially a labor-material substitution to the extent that overhead costs are fixed.

Finally, it should be noted that the extent to which overhead is fixed will depend greatly on the time horizon being considered. In the short run many facilities capital costs and indirect labor costs associated with the facilities capital will be relatively fixed while in the long run these costs will be variable. Thus in the short run θ may be relatively high while in the long run it may be relative low, perhaps even zero.

The intuitive[8] implication of this is that firms may design the nature of their facilities to allow for the long run first-best level of subcontracting given the expected or average level of business. However fluctuations of business away from the expected or average level will cause the firm to deviate from the short run first-best response in the fashion predicted above. Namely, there will be too much in-house production of cost-sensitive products and too much subcontracting of cost-insensitive products.

In particular then, overhead allocation may cause large distortions in the way firms respond to temporary rises or falls in their business level or in the way firms respond in the short run to permanent changes in their business level. However it may cause very little distortion in their long-run response to relatively permanent changes in their business level. Since the defense business is typically characterized as one involving both expected and unexpected fluctuations in business, the question of whether or not there are large short-run incentive problems is probably an important issue.

CHAPTER 4
FORMAL ANALYSIS: EQUILIBRIUM

A. Introduction

The previous chapter explained the nature of the firm's incentives to distort direct labor use by examining the marginal effect of direct labor on profit for a single contract. However, technically speaking, it did not actually demonstrate that these distortions would occur in that it did not calculate equilibrium or optimal choices for the firm. This chapter will formally calculate equilibrium input choices for the firm and show that the expected distortions (based upon the analysis of chapter 3) occur.

The analysis of this chapter does not contribute a great deal of extra economic insight over that contributed by chapter 3. Showing the marginal effects identified in chapter 3 produce the expected equilibrium distortions is a relatively straightforward technical exercise. The fact that this part of the analysis contributes little extra economic insight is the reason for separating it in its own chapter. Readers less interested in technical aspects of the analysis may choose to move directly to chapter 5.

To the extent that the results of this chapter simply illustrate the intuitions developed in chapter 3, the intuitions will not be repeated here. Thus this chapter will be somewhat terse and technical. However some minor new results are obtained in the equilibrium analysis and these will be explained more fully.

B. The General Problem

The general problem of the firm is to choose inputs to maximize its profits subject to the constraints on its input choice reflecting technological possibilities. Recall that profits are given in (3.1) by $\Gamma(L,M,Z,J)$. Thus the firm's problem is

$$(4.1) \qquad \text{Maximize} \quad \Gamma(L, M, Z, J)$$

$$(4.2) \qquad \text{subject to} \quad (L, M, Z, J) \in P$$

where P denotes the feasible set of inputs. The different cases considered below will correspond to different definitions of P.

To avoid discussion of trivial cases where the firm is indifferent between everything it will be assumed that at least one product's revenues are not totally cost-sensitive. That is, for some product i

$$(4.3) \qquad \phi_i'(C_i) < 1$$

for all $C_i \geq 0$.[9]

C. Pure Waste

Let (L^F, M^F, Z^F, J^F) denote the vector of inputs required to produce the desired outputs. In the pure waste case the firm can choose to increase input usage above this level if it wants. Formally

$$(4.4) \qquad P = \{L, M, Z, J): (L, M, Z, J) \geq (L^F, M^F, Z^F, J^F)\} \quad .$$

Proposition 1 showed that Γ is nonincreasing in M, Z, and J. Therefore there is no reason to expect the firm to incur waste in any variable but L.

(The firm can always do at least as well by not incurring waste in these other variables.) Therefore it will be assumed that the firm chooses efficient levels for all inputs except possibly for L. Let $\Gamma(L)$ denote the firm's objective function in this reduced problem.

(4.5) $\Gamma(L) = \Gamma(L, M^F, Z^F, J^F)$.

The firm's problem is as follows.

(4.6) Maximize $\Gamma(L)$

(4.7) subject to $L_i \geq L_i^F$ for every i.

It will be assumed that (4.6)-(4.7) has a unique solution characterized by its first order conditions. The solution is calculated in appendix B and only the interesting characteristics of the solution will be reported here. All proofs are in appendix B. The characteristics will be reported as a series of propositions. Let asterisks denote the values of the variables in the solution--i.e., L_i^* is the optimal labor choice for product i, C_i^* is the level of cost resulting in the optimal solution, etc. Let W denote the subset of products for which waste occurs and N denote the subset of products for which no waste occurs. Formally,

(4.8) $L_i^* > L_i^F$ *for* $i \in W$

(4.9) $L_i^* = L_i^F$ *for* $i \in N$.

Proposition 3 now presents the basic characterization. Namely, products whose revenues are more cost-sensitive will be the ones exhibiting waste.

Proposition 3:

Choose i, j ∈ W and k ∈ N. Then

$$\phi_i'(C_i^*) = \phi_j'(C_j^*) \geq \phi_k'(C_k^*). \tag{4.10}$$

Proposition 3 also states that all contracts in W will exhibit the same cost-sensitivity. The reason for this is clear. If one contract in W was more cost-sensitive than another, then the firm could increase profits by increasing waste on the former and reducing it on the latter.

Proposition 4 states that waste is never incurred on *all* of the products.

Proposition 4:

N is non-empty.

The intuition for this is very clear. The purpose of incurring waste is to shift overhead. If waste is being incurred on all products then the same shifting could be accomplished by reducing all waste levels until the waste level for one product was zero. Waste is reimbursed only partially. Therefore if the same overhead allocation could be produced with lower waste levels, then the firm's profits would be greater.

Proposition 5 makes a weaker statement about the non-emptiness of the set W. In general it may be the case that no waste is incurred. However, if at least one product is completely cost-sensitive at the cost levels existing under no waste then the firm will always find it optimal to incur some waste on that product. In particular, then, W will not be empty.

Proposition 5:

Suppose that

(4.11) $\phi_i'(C_i^F) = 1$

for some product i. Then $i \in W$.

D. Input Substitution

In chapter 3 input substitution between labor and material and between labor and capital were considered as two separate problems. This was analytically useful because the separate considerations involved in each type of substitution could be clearly understood. However in general the firm will simultaneously consider substitutions between all three inputs. Therefore this section will demonstrate that the expected distortions in direct labor occur in a more general model which potentially allows substitutions between all three variables.[10]

Assume that the joint inputs remain fixed at some level J^*. For each product the firm can choose any vector of product-specific inputs satisfying

(4.12) $L_i = f^i(M_i, Z_i)$

for some function f^i. Thus the feasible set of inputs is

(4.13) $P = \{L, M, Z, J): J = J^* \text{ and } L_i = f^i(M_i, Z_i) \text{ for every } i\}$.

Three definitions of various types of optimality will be useful before describing the properties of f^i. For any input choices the total product-specific cost is given by

(4.14) $L_i + M_i + Z_i$.

Substitution of (4.12) into (4.14) yields

(4.15) $f^i(M_i, Z_i) + M_i + Z_i$.

An input vector is first best if it minimizes this cost.

Definition:

An input vector $(\hat{L}_i, \hat{M}_i, \hat{Z}_i)$ is first best if it minimizes (4.15) and satisfies (4.12).

An ordered pair of inputs will be called second best given the third input if it minimizes cost given the third input.

Definition:

The ordered pair $(\hat{L}_i, \hat{M}_i)$ is second-best given Z_i if $(\hat{L}_i, \hat{M}_i, \hat{Z}_i)$ minimizes (4.14) subject to (4.12) and subject to $Z_i = \hat{Z}_i$. All other notions of second best for other ordered pairs of inputs are defined analogously.

The properties that f^i is assumed to satisfy will now be formally listed. A discussion will follow.

<u>Properties of f^i</u>:

(a) The function f^i is defined over the non-negative reals and maps into the non-negative reals. It is twice continuously differentiable.

(b) There is a unique first-best input vector. Denote it by (L_i^F, M_i^F, Z_i^F).

(c) There is a unique second best (L_i, M_i) given Z_i. Let $L_i^s(Z_i)$ and $M_i^s(Z_i)$ denote the two functions determining these values.

(d) There is a unique second-best (L_i, Z_i) given M_i. Let $L_i^S(M_i)$ and $Z_i^S(M_i)$ denote the two functions determining these values.

(e) (4.16) $f^i_M < 0$

(4.17) $f^i_Z < 0$

(f) (4.18) $f^i_{MM} > 0$

(4.19) $f^i_{ZZ} > 0$

(4.20) $f^i_{MM}f^i_{ZZ} - (f^i_{MZ})^2 > 0$

(g) (4.21) $f^i_{MZ} < 0$

(4.22) $f_M f_{MM} - f_Z f_{MZ} > 0$

(4.23) $f_Z f_{ZZ} - f_M f_{MZ} > 0$

Assumptions (a)-(d) simply require f^i to be a smooth function with solutions to the various cost-minimization problems of interest. Assumption (e) states that Z_i and M_i are substitutes for L_i and assumption (f) simply requires f^i to be convex. Given the above assumptions, assumption (g) is simply equivalent to the assumption that all inputs are strong substitutes in the sense that the second best inputs given the third input are both decreasing in the third input. That is, if the third input goes up then it is optimal to reduce use of both of the other inputs. This is straightforward to show so it will not be formally demonstrated. The only role that assumption g plays is to mildly strengthen the nature of the conclusions at one step in the analysis. This step will be identified below.

The firm's optimization problem can now be formalized as follows. Let $\Gamma(L, M, Z)$ denote the firm's profits when J is held at its fixed value--i.e.,

(4.24) $$\Gamma(L, M, Z) = \Gamma(L, M, Z, J^*) \quad .$$

Then the firm's problem can be written as

(4.25) Maximize $\Gamma(L, M, Z)$

(4.26) subject to $L_i = f^i(M_i, Z_i)$ for every i.

It will be assumed that a unique interior solution exists to (4.25)-(4.26) characterized by the first order conditions. The solution is calculated in appendix C and only the interesting characteristics of the solution will be reported here. All proofs are in appendix C. Let asterisks denote the values of variables in the solution--i.e., (L_i^*, Z_i^*) is the solution for product i, C_i^* is the resulting cost for product i, A^* is the resulting weighted average cost-sensitivity, etc.

Proposition 6 now states the major result of this part. In equilibrium, the firm uses too much (too little) direct labor on products which are of above average (below average) cost-sensitivity.

Proposition 6:

(4.27) $$L_i^* \gtreqless L_i^F \Leftrightarrow \phi_i'(C_i^*) \gtreqless A^*$$

This is, of course, precisely the expected result based on the analysis of chapter 3 so no further explanation will be offered. It should be noted that the expected distortions also occur with respect to the second best criteria. This is stated as Proposition 7.[11]

Proposition 7:

(4.28) $$L_i^* \gtreqless L_i^S(Z_i^*) \Leftrightarrow \phi_i'(C_i^*) \gtreqless A^*$$

(4.29) $$L_i^* \gtreqless L_i^S(M_i^*) \Leftrightarrow \phi_i'(C_i^*) \gtreqless A^*$$

One final comment regarding the issue of pure waste will be made before concluding this part. The formal model considered in this part did not allow the firm to engage in pure waste. However it is straightforward to allow the firm this additional option and to show that the firm will never have the incentive to engage in any type of pure waste, including direct labor waste. The intuition for and interpretation of this result was discussed in section 3E.

E. Subcontracting

As in section D, assume that J is fixed at some level J^*. Then the feasible set is defined by

(4.30) $$P = \{(L, M, Z, J) : Z_i = g_i(L_i);\ M_i = h_i(L_i);\ J = J^*\} \quad .$$

Assume that a unique level of first best inputs exists for every i. Denote each of these by (L_i^F, M_i^F, Z_i^F). They satisfy the following program:

(4.31) $$\underset{L_i,\, M_i,\, Z_i}{\text{Minimize}} \quad 1 + g_i(L_i) + h_i(L_i)$$

(4.32) $$\text{subject to} \quad M_i = h_i(L_i)$$

(4.33) $$Z_i = g_i(L_i)$$

Furthermore assume that the objective function (4.31) is single-peaked.

Let $\Gamma(L, M, Z)$ denote the firm's profits when J is held at its fixed value as defined by (4.24). Then the firm's problem can be written as follows.

(4.34) Maximize $\Gamma(L, M, Z)$

(4.35) subject to $M_i = h_i(L_i)$

(4.36) $Z_i = g_i(L_i)$

As usual, it will be assumed that a unique interior solution to (4.34)-(4.36) exits which is characterized by the first order conditions. The formal analysis and all proofs are confined to appendix D and only the major qualitative results will be reported here. Let variables with a superscript of "*" denote the values the variables assume under the solution. Proposition 8 now states the major result.

Proposition 8:

(i) Suppose that $[R^{M^*} - g_i'(L_i^*)] > 0$. Then

(4.37) $$L_i^* \gtreqless L_i^F \Leftrightarrow \phi_i'(C_i^*) \gtreqless A^*$$

(ii) Suppose that $[R^{M^*} - g_i'(L_i^*)] < 0$. Then

(4.38) $$L_i^* \gtreqless L_i^F \Leftrightarrow \phi_i'(C_i^*) \lesseqgtr A^* .$$

(iii) Suppose that $[R^{M^*} - g_i'(L_i^*)] = 0$. Then

(4.39) $$L_i^* = L_i^F$$

or

(4.40) $$\phi_i'(C_i^*) = 1 .$$

These, of course, are precisely the expected results based on chapter 3. In particular, recall that chapter 3 argued that case (i) is the most likely to actually apply to real cases of interest. In this case the qualitative nature of the direct labor distortions is exactly the same as for the input substitution case.

CHAPTER 5

EMPIRICAL ESTIMATES OF THE MAGNITUDE OF THE INCENTIVE EFFECTS

A. Introduction

This chapter will attempt to assess the empirical significance of the incentive effects described in this paper. The method for doing so will be as follows. Chapter 3 developed formulas which determine the marginal impact of direct labor usage on profit as a function of various parameters, including the overhead rate and cost-sensitivity of the firm's contracts. This chapter will substitute in plausible values for these parameters and thus estimate plausible values for the marginal impact of direct labor usage on profit.

It will be seen that the estimated effects are quite significant. For example, it is estimated that a dollar of direct labor waste on a cost-sensitive defense contract might increase a typical firm's profit by between $1.20 and $1.44. That is, there is a CPPC effect of 20 percent to 44 percent.

One remark regarding interpretation should be noted about these estimates. In the equilibrium calculated in chapter 4 the firm will have taken advantage of all such opportunities to increase its profits and the marginal effect of direct labor on profit will generally be zero. (This is the first order condition.) Thus in the context of the model of chapter 4, one should interpret the calculations of this chapter as providing plausible estimates of the incentives a firm might face to engage in pure waste prior to actually doing so. Also, it should be noted that the model of chapter 4 did not allow auditing to play any role at all in restraining firms' waste. In reality, firms may often perceive that there are positive marginal returns to engaging in direct labor distortions but that auditing prevents them from doing so. Thus one could also interpret the calculations of this chapter as providing estimates of the actual equilibrium incentives in a more complicated model where auditing partially restrains defense firms' behavior.

In order to make best use of the actual data it will be useful to complicate the formal model of chapter 3 in one respect. The one major exception to the general rule that "most defense firms allocate most of their overhead based on direct labor" concerns an overhead element usually labelled general and administrative (G&A). This basically consists of the cost of central management functions. It is typically allocated over a base which includes direct labor as one of its elements but also includes other elements. Although it is small enough that one could simply ignore the entire G&A pool and produce estimates which are relatively close to correct it is fairly straightforward to alter the formulas of chapter 3 to explicitly include the effects of the G&A pool.

None of the basic intuitions of chapter 3 are altered. One of the factors determining the size of the firm's incentive to shift overhead is the number of dollars of overhead that a dollar of direct labor attracts. Formally modelling the more complicated way that the G&A pool is allocated simply produces a more refined estimate of the number of dollars of overhead that a dollar of direct labor attracts. In particular, direct labor is not as effective at shifting dollars in the G&A pool as other overhead dollars.

The consideration of the more complex manner in which G&A is allocated simply produces a more complex set of formulas which yield few new qualitative results. This feature was not included in the previous chapters because their goal was to clearly and simply demonstrate the basic ideas of this paper. However for purposes of actual estimation it is more important to include the complication. In particular this produces a more conservative estimate than would be had by simply assuming that G&A is entirely allocated according to direct labor. Since the conclusion of this chapter is that the incentive effects are large, it is important to remove such potential upward biases from the estimation procedure to the extent possible.

Section B will formally describe the two-pool overhead allocation system that it will be assumed that the firm uses. Section C will then derive the analogous formulas to those in chapter 3. Sections D-G will develop plausible values for the various parameters in the formulas. Then section G will present the empirical estimates of the marginal impact of direct labor on profit for the various cases of interest.

B. The Generalized Model: Description

The generalized cost allocation model used in this chapter will be exactly the same as that described in section 2C except for one additional feature. Direct labor and material are still denoted by L_i and M_i. The overhead described in section 2C still exists, still can be broken into product-specific and joint components, and is still allocated according to direct labor. However it will now be called manufacturing and engineering (M&E) overhead instead of simply overhead. Similarly the overhead rate, R^M, will now be called the M&E overhead rate. Thus equations (2.6)-(2.9) are still true. The one difference in the generalized model is that it will be assumed that an additional overhead pool exists which will be called the general and administrative (G&A) pool. Let G denote its dollar value. It will be assumed that all of the costs in G are joint.

The G&A pool's major distinguishing feature is that it is allocated in a somewhat more complicated fashion than is the M&E pool. Define the total cost input for contract i, denoted by T_i, to be direct labor and material plus the allocated share of the M&E pool.

$$T_i = M_i + L_i(1 + R^M) \tag{5.1}$$

Then the G&A pool is allocated according to total cost input. Let G_i denote the amount of G&A overhead allocated to contract i. It is given by

$$G_i = \frac{T_i}{\sum_{k=1}^{n} T_k} G . \tag{5.2}$$

Let R^G denote the G&A overhead rate given by

$$R^G = \frac{G}{\sum_{k=1}^{n} T_k} . \tag{5.3}$$

Then (5.2) can be rewritten as

$$G_i = T_i R^G . \tag{5.4}$$

The total cost of contract i, denoted by C_i, is given by

$$C_i = L_i + M_i + V_i + G_i \tag{5.5}$$

which can be rewritten as

$$C_i = (1 + R^G)\{L_i(1 + R^M) + M_i\} \tag{5.6}$$

Before proceeding to the calculation of formulas for the marginal effect on profit, one further simplification will be introduced. In the analysis of the single-pool cost allocation system in chapter 3 the average cost-sensitivity given by

$$(5.7) \qquad A = \sum_{i=1}^{n} \left(\frac{L_i}{\sum_{k=1}^{n} L_k} \right) \phi_i'(C_i) \ .$$

played a role. This is because the weights corresponded to overhead shares. In the two-pool analysis of this chapter, the parameter A will continue to play a role because M&E overhead is still allocated according to these shares. However G&A is allocated according to different shares. In particular, contract i will receive the share

$$(5.8) \qquad \frac{T_i}{\sum_{k=1}^{n} T_k} \ .$$

of G&A overhead. Therefore it should not be surprising that the weighted average cost-sensitivity calculated according to these weights will also play a role. Call this value A^T.

$$(5.9) \qquad A^T = \sum_{i=1}^{n} \left(\frac{T_i}{\sum_{k=1}^{n} T_k} \right) \phi_i'(C_i) \ .$$

In general there is no reason to believe that A and A^T will be the same. Generally speaking, this would only be true if the ratio

$$(5.10) \qquad L_i/M_i$$

stayed constant across contracts. However, for purposes of empirical implementation no data is available on how the ratio in (5.10) varies between contracts and how this variation is correlated with cost-sensitivity. Therefore it will be assumed that A^T and A are equal. Let A denote this common value.

C. The Generalized Model: Analysis

This section will basically repeat the analysis of chapter 3. It will be seen that the existence of the extra overhead pool alters the formulas in an extremely intuitive fashion and that almost all of the intuition and analysis of chapter 3 still applies in a slightly altered fashion.

Proposition 9 is the analogue to Proposition 1 and presents the derivatives of profit with respect to the input variables. Since the proofs simply involve straightforward differentiation, they will not be presented.

Proposition 9:

$$(5.11) \qquad \frac{\partial \Gamma}{\partial M_i} = \left(\phi_i'(C_i) - 1\right) + R^G\left(\phi_i'(C_i) - A\right)$$

$$(5.12) \qquad \frac{\partial \Gamma}{\partial Z_i} = A - 1$$

$$(5.13) \qquad \frac{\partial \Gamma}{\partial M_j} = A - 1$$

$$(5.14) \qquad \frac{\partial \Gamma}{\partial G} = A - 1$$

$$(5.15) \qquad \frac{\partial \Gamma}{\partial L_i} = \left[R^M + R^G(1 + R^M)\right]\left[\phi_i'(C_i) - A)\right] + \left[\phi_i'(C_i) - 1\right]$$

Each of the formulas in Proposition 9 will now be compared to the analogous formula in Proposition 1. First consider (5.11). Now direct material attracts R^G dollars of overhead. Thus the second term is added to (5.11) to reflect the effect on profit of shifting R^G dollars of overhead. The next three formulas show that the marginal effect of increasing any type of overhead still equals A - 1 just as for Proposition 1. Finally consider (5.15). Let D denote the following term in (5.15).

$$D = R^M + R^G(1 + R^M) \tag{5.16}$$

The difference between (3.6) and (5.15) is that the term "R^M" in (3.6) is replaced by the term "D" in (5.15). The reason for this is straightforward. In the single pool case one dollar of direct labor attracted R^M dollars of overhead. This is why R^M was the appropriate value to use in (3.6). However in the multiple pool case of this section one dollar of direct labor attracts D dollars of overhead. It attracts

$$R^M \tag{5.17}$$

dollars from the M&E pool. However this creates $(1 + R^M)$ dollars of total cost input which in turn attract

$$R^G(1 + R^M) \tag{5.18}$$

dollars from the G&A pool. The sum of (5.17) and (5.18) is D.

Thus there are only two differences in the multiple pool case. First, direct material now attracts R^G dollars of overhead instead of 0 dollars of overhead. Second, direct labor attracts D dollars of overhead instead of R^M

dollars of overhead. All of the formulas for the multiple-pool case are simply the natural analogues to the formulas for the single pool case where adjustments are made for these two differences.

Now consider input substituion. Just as in chapter 3, view L_i as the choice variable for the firm with the required values of Z_i and M_i given by (3.13) and (3.14). Let $\pi(L)$ denote the firm's profits. Proposition 10 presents the general formula for the marginal effect of direct labor on profit. This is the analogue to Proposition 2. The proof is similar to that for Proposition 2 and will not be supplied.

Proposition 10:

$$(5.19) \quad \frac{\partial \pi}{\partial L_i} = [1 + R^G][R^M - g_i'(L_i)][\phi_i'(C_i) - A] + [1 + h_i'(L_i) + g_i'(L_i)][\phi_i'(C_i) - 1] \ .$$

These general formulas will now be applied to all of the cases considered in chapter 3. The assumptions defining each case will not be repeated here. The reader should refer back to chapter 3 as necessary.

1. **Pure Waste**

Formula (5.15) gives the marginal effect of direct labor waste on profit. As just stated the only difference in the multiple pool case is that R^M is replaced by D because now one dollar of direct labor attracts D dollars of overhead.

2. **Labor-Material Substitution**

The analogue to (3.19) is now given by

$$(5.20) \qquad \frac{\partial \pi}{\partial L_i} = (D - R^G) \; [\phi_i'(C_i) - A)] \; .$$

The difference between these two formulas is that the term "R^M" in (3.19) has been replaced by the term "D - R^G" in (5.20). The reason for this is straightforward. In the single-pool case substitution of a dollar of direct labor for a dollar of direct material attracted R^M dollars of overhead to contract i. This is why R^M is the appropriate value to use in (3.19). However in the multiple pool case the situation is slightly more complex. The increased dollar of direct labor attracts D dollars of overhead but the reduced dollar of direct material takes away R^G dollars of overhead. The net amount of overhead attracted is D - R^G dollars.

3. Labor-Overhead Substitution

The analogous formula to (3.22) is

$$(5.21) \qquad \frac{\partial \pi}{\partial L_i} = (1 + D) \; [\phi_i'(C_i) - A)] \; .$$

Thus the only difference between (3.22) and (5.21) is that the term "1 + R^M" is replaced by the term "1 + D". The reason for this is as explained above--i.e., one dollar of direct labor now attracts D dollars of overhead.

4. Subcontracting

The analogous formula to (3.27) is

$$(5.22) \qquad \frac{\partial \pi}{\partial L_i} = (1 + R^G) \; [R^M - g_i'(L_i)] \; [\phi_i'(C_i) - A] \; .$$

The only difference between (3.27) and (5.22) is that (3.27) is multiplied by $(1 + R^G)$ to yield (5.22). The reason for this is as follows. By assumption, we are considering input changes which have a net effect of zero--i.e., the sum of the changes equals zero. Therefore both total cost input (total cost minus G&A) and G&A remain constant. Therefore R^G also remains constant. This means that the marginal effect on profit can be calculated in two steps.

Step #1: Ignore the G&A pool by assuming $R^G = 0$. Calculate the change in profit using the formula from chapter 3.

Step #2: Multiply by $(1 + R^G)$ to reflect the change in G&A allocation.

This yields (5.22).

Therefore all of the analysis of (3.27) still applies to this case. The only difference is that the effect is multiplied by $(1 + R^G)$ which has no qualitative effect. In particular all of the discussion surrounding the term

$$(5.23) \qquad R^M - g_i'(L_i)$$

still applies. The formula for the example where M&E overhead has a fixed and linear component is now[12]

$$(5.24) \qquad \frac{\partial \pi}{\partial L_i} = \theta(D - R^G)\ [(\phi_i'(C_i) - A)]$$

where, recall, θ is the proportion of fixed M&E overhead. This is the formula that will be used for estimation purposes. Note that the same relationship between the effects for the subcontracting and labor-material substitution cases still is true. The former equals θ times the latter. The same intuition still explains this. Increased labor use due to increased in-house production is essentially a labor-material substitution to the extent that overhead is fixed.

D. Empirical Estimation: Overview

Table 5.1 displays the formulas determining the marginal impact of direct labor on profit for all the cases of interest.

Table 5.1
The Marginal Impact of Direct Labor on Profit

Case	Formula
Pure Waste	$D[\phi_i'(C_i) - A] + [\phi_i'(C_i) - 1]$
Labor-Material Substitution	$(D - R^G)\ [\phi_i'(C_i) - A]$
Labor-Overhead Substitution	$(D + 1)\ [\phi_i'(C_i) - A]$
Subcontracting	$\theta(D - R^G)\ [\phi_i'(C_i) - A]$

The first term of all four formulas is the same. It gives the profit from overhead shifting and is of the form

$$(5.25) \qquad x[\phi_i'(C_i) - A]$$

where x is the number of dollars of overhead shifted by one dollar of direct labor (and varies from case to case) and $[\phi_i'(C_i) - A]$ is the profit per dollar of overhead shifted (and is the same for every case). This is the only term for the three input substitution cases since by assumption an increase in direct labor is coupled with an equal decrease in other inputs. For the pure waste case one must also consider the impact on profit from the increase in direct cost due to the expenditure on direct labor. This is given by the second term of that formula.

Therefore in order to estimate plausible values for the size of the marginal impact of direct labor on profit one must determine plausible values for three groups of parameters. The first group is overhead rates, R^M and R^G, and the second group is the single parameter θ. These determine the value of x. The third group is the cost sensitivity parameters $\phi_i'(C_i)$ and A.

Each of these three groups will now be discussed in turn.

E. Overhead Rates

This section will develop plausible estimates to use for the overhead rates, R^M and R^G, by determining the average values of these two rates for four major aerospace contractors in 1987. The four contractors are General Dynamics Forth Worth Division, Grumman Aerospace Company, McDonnell Aircraft Company, and Northrop Aircraft Company. The data for these calculations is from a study of the cost accounting systems of these four firms for the years 1974-1987 conducted by the Institute for Defense Analysis [McCullough and Balut 1990]. Readers desiring more data and a fuller explanation should directly consult this paper.[13]

First it should be noted that the overhead allocation process for these four firms is essentially as described by the generalized model in section B above. All four firms allocate G&A according to total cost input. Almost all overhead other than G&A is allocated according to direct labor. Many of the firms divide M&E overhead into a number of smaller pools and allocate each pool according to a particular type of direct labor. For example, many firms have separate manufacturing and engineering overhead pools which are allocated, respectively, according to manufacturing direct labor and engineering direct labor. However this subdivision does not cause any essential changes and thus will be ignored. In reality the overhead rates between pools will vary somewhat and the incentive to distort each type of direct labor will vary accordingly. This chapter can be viewed as calculating the average incentive.

Table 5.2 presents the breakdown of costs into various cost pools and then table 5.3 presents the calculations of R^M and R^G, and D.

Table 5.2

Breakdown of Costs

Cost Type	000s of $	% of Total
Direct labor	2,333,994	20.1
Direct material	6,025,409	51.9
Overhead	3,259,095	28.0
G&A	940,243	8.1
M&E	2,318,852	19.9
Total	11,618,498	100.0

Table 5.3

Value of Overhead Rates

Rate	Value
R^M	.99
R^G	.09
D	1.17

A number of adjustments had to be made to the data from McCullough and Balut [1990] in order to p duce table 5.2. A complete description of these adjustments is contained in appendix E. The four most important adjustments will be briefly noted here. First, allowable independent research and development and bid and proposal (IR&D/B&P) expenditures are included in the G&A pool.[14] This is because IR&D/B&P is required to be allocated in the same manner as G&A. Also note that only *allowable* expenditures (i.e., expenditures which the DoD recognizes for pricing purposes) were included since only these affect defense products' prices.

Second, there is a small amount of overhead called material handling overhead which is allocated according to some measure of direct material use. This has simply been included as part of direct material. The overhead is too small to make any difference so is ignored for expositional clarity. Also, there are a variety of direct charges which are neither labor nor material. These are called other direct charges (ODCs). The largest of these is directly charged computer time. From the standpoint of this paper they are mathematically equivalent to direct material (i.e., they are a direct charge which is not used as an allocation base) so they have been included in direct material. Finally, some readers may wonder why direct material is such a large figure. This is because it includes all directly charged subcontracted items.

Third, fringe benefits for direct labor have been included as part of direct labor. Firms normally classify fringes as part of overhead. However there is no incentive problem created by placing fringes in the overhead pool. This is because the firm cannot spend an extra dollar on direct labor without also spending proportionately more on fringes as well. One might call these *linked costs*. Since no incentive problem is created by placing fringes in overhead, the correct procedure for estimating the magnitude of incentive effects is to remove them from the overhead pool and reclassify them as direct.

Fourth, the McCullough and Balut [1990] data did not include the elements of economic cost that the DoD labels as a "profit." These are primarily a return for risk bearing, working capital and facilities capital. Other than for facilities capital this exclusion is of no great concern. This is because the profit for each contract is directly calculated and no other costs are allocated based on these charges. Thus they can be viewed as direct charges which bear no overhead and they are therefore irrelevant to the calculations of this paper. However facilities capital profit is allocated according to direct labor use just as the M&E pool. Therefore from the standpoint of this paper facilities capital profit is mathematically equivalent to any other M&E cost so it has been added to the M&E pool.

These are the four major adjustments that were made to the McCullough and Balut [1990] data. The only truly significant impact was created by the third adjustment--reclassifying fringes as direct. This lowers overhead rates and thus reduces the magnitude of the estimated incentives to distort direct labor.

To conclude, it should be noted that, while the calculations of this section rely on data from only four aerospace firms, based on extensive discussions with industry and government personnel, I believe that these four firms are in fact representative of a broad segment of the defense industry in two senses. First, their practice of allocating almost all overhead except G&A based on direct labor and allocating G&A based on total cost input is the norm. Second, the overhead rates of these four firms are very typical.

Some extra empirical evidence is available on this second point. The Logistics Management Institute [Meyers et. al. 1985] has published an average cost breakdown for 5,434 (randomly selected) contracts negotiated in 1980-82. Using this data, one can derive estimates for the overhead rates as displayed in table 5.4. These values are very close to those estimated in table 5.3[15] The derivative of these estimates is presented in appendix F.

Table 5.4

Estimated Overhead Rates
Using LMI Data

Rate	Value
R^M	.83
R^G	.14
D	1.09

F. **Fixed Overhead As A Share of Total Overhead**

Both the DoD and defense firms routinely calculate linear regressions of a firm's total overhead expenditures on direct labor and other variables. The reason for this is that such regressions provide the basis for estimating future overhead rates and thus future costs. (One directly estimates future direct labor use and then applies the regression equation to estimate future overhead.) This technique is in fact widely used by both commercial and defense firms and is often given the label "flexible budgeting" in standard commercially-oriented accounting texts.[16] Thus there is perhaps some reason to believe that it is reasonably accurate to assume that a linear relationship exists (in the relevant range) between direct labor and overhead as the amount of business in the firm varies.

Unfortunately most of these studies are proprietary and not publicly available. An exception is reported in McCullough and Balut [1990]. They run the following regression for each of the four aerospace firms in their main study plus two additional firms, Lockheed-California and Sikorsky.[17]

$$(5.26) \qquad y_t = \alpha + \beta_1 x_{1t} + \beta_2 x_{2t} \ .$$

The notation is as follows:

y_t, total overhead expenditures in year t

x_{1t}, net book value of assets in year t

x_{2t}, total direct labor expenditures in year t[18]

$\bar{x}_1$, the mean of x_{1t}

$\bar{x}_2$, the mean of x_{2t}

The net book value variable is added in an attempt to distinguish between the long and short run. In particular the authors interpret the amount of overhead which is fixed in the short run as being given by

$$(5.27) \qquad F = \alpha + \beta_1 \bar{x}_1 \ .$$

Recall that section 3G argued that short run incentives are significant because of the prevalence of both expected and unexpected fluctuations in defense firms' business levels. Therefore this section will estimate the magnitude of the short run incentive effects, i.e., the value of F given by (5.27) will be used to calculate θ.

The value of θ can now be calculated. Define ψ to be the share of total overhead that is fixed in the short run. It is given by

$$\psi = \frac{F}{\alpha + \beta_1\overline{x_1} + \beta_2\overline{x_2}} \tag{5.28}$$

where F is given by (5.27). McCullough and Balut [1990] calculate ψ for each of the six firms and report its average value. This is .58. However this is *not* the value of θ since θ is the share of *M&E* overhead that is fixed. It seems reasonable to conjecture that most G&A is relatively fixed in the short run. Thus θ will be less than .58. To correct for this it will be assumed that all G&A is fixed. This is conservative in that it yields the smallest value of θ. From table 5.2 G&A is 29 percent of total overhead. Thus θ is given by

$$\theta = \frac{.58 - .29}{1 - .29} = .41 \quad . \tag{5.29}$$

This is the value of θ which will be used for estimation purposes.

G. Contract Mix by Cost Sensitivity

Development of the overhead rates to use for estimation purposes was relatively straightforward and noncontroversial since real data exists. The estimation of θ was more problematic but was at least still based on real data.[19] The question of what values the cost-sensitivity parameters ought to assume is difficult because no actual data exists.

For purposes of constructing estimates, this paper will assume that the firm does have some contracts which are extremely cost-sensitive and some contracts which are extremely cost-insensitive. In particular it will be assumed that contract 1 is perfectly cost-sensitive and contract n is perfectly cost-insensitive.

(5.30) $$\phi_1'(C_1) = 1$$

(5.31) $$\phi_n'(C_n) = 0$$

The marginal effect of direct labor changes on profit will be calculated for these two contracts. This provides estimates of the two extremes of incentive effects that the firm will experience.

The assumption that these two extreme cost-sensitivities exist does not appear unreasonable. As discussed in chapter 2, most students of military procurement would agree that prices on a wide variety of procurements are highly cost-based. For the other extreme, one can appeal to the existence of commercial products. Most major defense firms produce both commercial products and defense products in the same business segment. Data on the average values of commercial business will be supplied below. Even when a firm has no commercial business, it may be that the intense competition to obtain early contracts in a procurement program may mean that the price is determined quite independently of cost on these. This was also discussed more thoroughly in chapter 2.

The remaining, and more difficult question which must be addressed concerns the value of A, the average cost-sensitivity of all of the firm's contracts. The effect of the size of A on the estimates is determined by the fact that shifting one dollar of overhead to contract i produces a net change in profit of

(5.32) $$\phi_i'(C_i) - A$$

dollars. Thus for the cost-sensitive contract the incentive to shift overhead towards it will be larger as A grows smaller and will be at a maximum if A equals zero. The situation is reversed for the cost-insensitive contract.

This paper will consider four different estimates of A. The first estimate will simply be

(5.33) $$A = 0 .$$

This is not meant to be generally realistic or typical. It simply measures the maximum possible incentive which could exist to use too much labor on the cost-sensitive contract. This corresponds to a scenario where all contracts except contract 1 are completely cost-insensitive and contract 1 is extremely small.

The second estimate will be

(5.34) $$A = 1 .$$

This, in a similar spirit to that above, measures the maximum possible incentive which could exist to use too little labor on contract n. It corresponds to a situation where all contracts except contract n are completely cost-sensitive and contract n is extremely small.

The third estimate will be constructed by assuming that all of the firm's government contracts are completely cost-sensitive and all of the firm's commercial contracts are completely cost-insensitive. Then the industry average for the proportion of government business will be used to construct the value of A. Let G denote the fraction of direct labor used by the firm's government contracts. Then A is given by

(5.35) $A = G$.

In its last major statistical analysis of all major defense contractors, the DoD [1985] found that, on average, major defense contractors' business was 82.8 percent government and 17.2 percent commercial.[20] This yields an estimate for A of

(5.36) $A = .828$.

There is a sense in which this third estimate is biased upwards. Although it is reasonable to assume that all of a firm's commercial business is priced independently of accounting costs it is probably not as reasonable to assume that all of its defense business is perfectly cost-sensitive. At least a muted level of competitive forces will be at play on some of the firm's defense contracts. To the extent that some of a typical firm's defense business is less than perfectly cost-sensitive, this will tend to lower the value of A.

To attempt to account for this, the fourth estimate will be constructed using the (fairly arbitrary) assumptions that half of the firm's government business is perfectly cost-sensitive and half has a cost-sensitivity equal to .5. This yields a value for A of

(5.37) $A = .5[G + .5G]$

Substitution of $G = .828$ into (5.37) yields

(5.38) $A = .621$.

The estimates of $\partial\pi/\partial L_i$ derived using values of A of .828 and .621 will be interpreted as defining a plausible range of possible values for a typical defense firm. The estimates derived using values of A equal to 1 or 0 will be interpreted as defining the theoretical extremes which could occur.

H. Empirical Estimation

The parameter values determined in sections E-G can now be substituted into the formulas in table 5.1. The results of doing this are given in tables 5.5 and 5.6. Table 5.5 gives the results for $\phi_i'(C_i) = 1$ and table 5.6 gives the results for $\phi_i'(C_i) = 0$.

Table 5.5
The Marginal Impact of Direct Labor on Profit When $\phi_i'(C_i) = 1$

Case	Value of A			
	0	.621	.828	1
Pure waste	1.17	.44	.20	0
Labor-Material substitution	1.08	.41	.19	0
Labor-Overhead substitution	2.17	.82	.39	0
Subcontracting	.44	.17	.08	0

Table 5.6
The Marginal Impact of Direct Labor on Profit When $\phi_i'(C_i) = 0$

Case	Value of A			
	0	.621	.828	1
Pure waste	-1	-1.72	-1.97	-2.17
Labor-Material substitution	0	-.67	-.89	-1.08
Labor-Overhead substitution	0	-1.35	-1.80	-2.17
Subcontracting	0	-.27	-.36	-.44

First consider table 5.5. The marginal impact on profit is positive because the firm wants to increase direct labor on this contract. The effect is largest when A = 0 because then each dollar of shifted overhead generates a full dollar of profit. Thus the first column of table 5.5 is simply the number of dollars of overhead shifted by a dollar of direct labor.[21] Then subsequent columns are simply proportionate reductions in the first column as the value of profit per dollar of shifted overhead, $\phi_i'(C_i) - A$, decreases.

Four remarks should be noted about this table. First and most important, the magnitude of the incentive effect is extremely large. The two middle columns represent a plausible range of values. For the pure waste case, for example, the CPPC effect is between 20 percent and 44 percent. That is, burning a dollar and calling it direct labor generates between $1.20 and $1.44 of revenue. Second, the incentive effect for material-labor substitution is slightly smaller because material attracts G&A. Thus the net amount of overhead shifted is smaller. Third, the incentive effect for labor-overhead substitution is much larger because of the extra direct shifting this causes. It is essentially twice the size of the pure waste case with a plausible range of 39 percent to 82 percent. Fourth, the subcontracting distortion incentive is smallest because it only occurs to the extent that overhead is fixed. Even in the short run it was estimated that only 41 percent of the firm's M&E overhead is fixed. Thus the subcontracting incentive distortion equals 41 percent of the material-labor incentive distortion. The plausible range of the CPPC effect is between 8 percent and 17 percent.

Now consider table 5.6 which creates the same estimates when $\phi_i'(C_i) = 0$. The marginal effect on profit is negative because the firm wants to decrease direct labor use. Most of the same comments regarding the construction of the table and the resulting relationships between columns and rows as made above apply and will not be repeated. Three differences will be noted however. First, the largest incentive effect now occurs when A = 1 since this maximizes the absolute value of $\phi_i'(C_i) - A$. Second, the second term for the pure waste formula is no longer zero but minus one (i.e., if the firm could reduce direct labor expenditure by one dollar on a commercial contract it would earn a dollar of extra profit). The values reported in the pure waste row are thus relatively large in absolute value. However they are not particularly relevant because "negative waste" is not possible. Third, the plausible ranges of the CPPC effects determined by the middle two columns are much larger in table 5.6 than 5.5. The reason for this is that A is assumed to be closer to one than to zero (A is between .621 and .828). This means that the incentive effects on the cost-sensitive contract are smaller. However it also means that the incentive effects on the cost-insensitive contract are larger. In particular, then, a high value of A does not mean that all incentive distortions grow smaller. It simply changes where they occur.

CHAPTER 6
DISCUSSION

This chapter will discuss a number of the paper's results in more detail. The discussion will be organized into eight sections.

A. Significance of Input Substitution Distortions

One of the major results of this paper is to show that the firm will have the incentive to substitute inefficiently between inputs as well as pad direct labor. This is significant for three reasons. First, it shows that the incentives identified by this paper can affect a broad range of the firm's decisions involving potentially all aspects of its technology choice. Second, it means that attempting to deal with the problem by auditing is even less likely to be effective. This is because it is even more difficult for auditors to determine if inputs have been combined in efficient proportions than to determine if labor padding exists. Third, it means that distortions designed to increase revenue on cost-sensitive contracts will not be confined to cost-sensitive contracts. Firms will also have the incentive to purposely underuse direct labor on cost-insensitive contracts.

B. Welfare Analysis

This paper has settled for simply estimating the magnitude of the marginal incentives to distort input usage instead of continuing on to actually estimate an equilibrium welfare loss. This is because, while fairly reliable and plausible estimates can be created for the size of the marginal incentives, the same cannot be said for estimates of the equilibrium welfare loss. Two additional factors will affect the size of the welfare loss and both of these are difficult to empirically estimate. The first factor is the extent to which auditing can actually restrain inefficiency. The second factor is the marginal rate of substitution between inputs.

If one were to attempt to conduct such a welfare analysis it is important to note that there are two distinct types of losses occurring due to the firm's direct labor distortions, and depending upon one's point of view, one might want to include one or both of them in assessing the magnitude of the welfare loss. A simple example will make this point clear. Suppose a firm burns $100 on a defense contract and succeeds in raising price by $150 as described in the example in the introduction of this paper. The cost inefficiency equals $100. The increase in the firm's profit is $50. The sum of these two terms, $150, is the increase in the price paid by the government. From a social point of view the welfare loss is $100.

The question of greater interest regards the size of the loss to the government. The naive answer is $150, the size of the price rise. This is of course the correct answer in a single-period one-shot analysis. However, in reality the situation is more complex because the DoD and defense firms are involved in a long-term continuing relationship. It is almost certainly the case that the DoD is paying revenues greater than short-run incremental cost on almost all weapons it purchases. Thus it could almost certainly reduce price in the short run and succeed in still purchasing the same weapons. However, in the long run price must be above long-run incremental cost. Furthermore, joint costs of production must be paid by someone in order for the firm to exist in the long run. Current arrangements have the DoD pay some share and it is not clear that this share could be reduced without having firms exit. Finally, as I have argued elsewhere [Rogerson, 1989b], it may be that (for incentive-based reasons) the DoD indirectly funds some R&D by purposely paying more than long-run incremental cost on production contracts. Thus the impact of revenue reductions on R&D must also be considered.

The question of whether a defense firms' revenues from a product are too high or too low relative to the long-run incremental cost of producing the product is really a totally separate question from that of whether costs are too high or too low. This paper has only been concerned with the latter question. The former question involves a range of complex issues and is beyond the scope of this paper. The point being made here is that there is no reason to simply assume that revenues are too high relative to long-run incremental costs. Therefore there is no reason to assume that simple transfers from government to the firm represent a welfare loss to government.

Thus, in the absence of any other information, it is perhaps most reasonable to view the government's loss as also being $100. Generalizing from this example, government's loss due to the incentive problems identified in this paper ought to be viewed as equal to the loss due to cost inefficiency. In particular, the loss to government should not include simple transfers from government to the firm.

C. Future Trends

Overhead rates in both defense and commercial firms have been rising due to the effects of increased automation. This tends to lower direct labor costs and increase overhead costs under traditional accounting methods. This trend is likely to continue. This means that the incentive problems identified by this paper are likely to become more severe in the future.

For example, based on simple extrapolation of historic trends, McCullough and Balut [1990] predict that manufacturing direct labor will be 27 percent of its current level by the year 2020.[22] Therefore overhead rates based on manufacturing direct labor would increase by 370 percent (100 percent ÷ .27)! This means that all of the incentive effects identified by this paper would be 3.7 times as large.

D. Automation

Increased automation reduces direct labor usage and increases both capital usage and indirect labor usage associated with the physical capital. Thus automation has the effect of decreasing direct labor cost and increasing overhead cost. In particular, then, a prediction of this paper is that a defense firm will on average tend to underautomate production of its defense products and overautomate production of its nondefense products. Within its defense products, the extent of underautomation will be most severe on well-funded sole-source programs where competitive pressures are least severe.

It is a well-accepted stylized fact that defense production is underautomated.[23] There have been two related explanations given for this. The first is that DoD pricing formulas have not fully compensated firms for the true economic cost of facilities capital investment. The second explanation is that defense firms are unwilling to invest in long-lived facilities capital because government is generally unwilling to provide any sort of long-term contractual guarantees. The second argument is of course closely related to the first. To the extent the government refuses to provide long-term contractual guarantees, this increases the risk of investment and thus also increases the required return.

The contribution of this paper is to show that there may still be a very significant incentive for firms to underinvest in automation of defense production even if the economic cost of capital investment is being correctly calculated. Chapter 5 argued that plausible values for the CPPC effect on a cost-sensitive defense product might be between 39 percent and 82 percent.[24] Thus, even if the regulations succeed in correctly compensating the firm for its true facilities capital cost, the firm will still perceive that it can earn between 39¢ and 82¢ in pure economic profit by substituting $1 of direct labor for $1 of facilities capital costs.

This insight perhaps provides an explanation for a puzzling feature of the DoD's most recent adjustment to its formula for calculating a return to defense firms' facilities capital. Because of its concern that defense firms were under-automated, the DoD in 1987 significantly increased the allowed return on facilities capital which it uses for purposes of pricing contracts. As explained in appendix E, the normal return to facilities capital is now approximately 36 percent. The minimum allowable return is 25 percent and the maximum allowable return is 46 percent. The "puzzle" is simply that these numbers appear rather enormous. One possible explanation is that they are too large and regulators made a mistake. Another possible explanation is that the risks are extremely large and that the true cost of capital averages 36 percent for defense firms. This paper suggests a third explanation. Suppose that there is a significant CPPC effect on direct labor, perhaps on average equal to 40 percent.[25] Then in order for defense firms to be indifferent between substituting one dollar of direct labor for one dollar of (annualized) capital cost it would be necessary to pay the firm an interest rate equal to 1.4 times its true cost of capital. In particular, if its true cost of capital were 26 percent, it would be necessary to pay 36 percent in order to induce it to make the correct capital-labor substitution. Thus it may be that the very high rates of return in the new policy are truly required in order to induce firms to make first-best automation decisions. However, this is not because the true cost of capital is this high. Rather, it is because of the input distortion incentives created by the overhead allocation process.

E. Subcontracting

The prediction of this paper is that a defense firm will keep too much production in-house for its defense products and subcontract too much for its commercial products. Within its defense business, the tendency to keep too much production in-house will be most pronounced for well-funded sole source procurements which are subject to the least competitive pressure.

This prediction seems broadly consistent with the stylized facts and may explain them better than existing theories. The DoD seems concerned that prime contractors may not make optimal "make-or-buy" decisions and a considerable amount of the DoD's cost-monitoring activity is devoted towards reviewing the adequacy of such decisions.[26] Both Peck and Scherer [1962] and Gansler [1980] suggest that the general concern is that defense firms tend to want to produce too much of their defense products in-house.[27]

Peck and Scherer suggest that in some cases this effect may be explained by the fact that a prime contractor wants to develop expertise in a new area by building a subcomponent itself rather than subcontracting to a firm which already has the expertise. There is undoubtedly some truth to this argument.

The contribution of this paper is to suggest that the incentives for this behavior may be much more general and not simply apply to the scenario depicted by Peck and Scherer. That is, regardless of any strategic implications for future business, a defense firm may have a strong incentive to reduce subcontracting on its defense business in order to shift overhead towards it.

Gansler's [1980] explanation for firms' behavior comes closer to that of this paper. He states the following.

> [I]n defense work profit is directly related to cost, and thus in the defense "make or buy" decision one is faced with the desirability of maximizing cost.[28]

Thus Gansler is essentially positing that CPPC pricing is the source of the problem. However, as argued in the introduction to this paper, the significance of CPPC pricing (if it exists at all) is relatively small. Furthermore, the simple assumption that firms want to increase cost does not provide a particularly compelling explanation for why firms should in particular choose to employ too little subcontracting. For example, employing too much subcontracting would also increase cost. So would employing the optimal level of subcontracting but simply paying higher prices to subcontractors. This paper's theory specifically predicts the exact type of behavior which occurs. Namely there will be too little subcontracting of defense products.

Gansler's theory provides an example of the general point made in the introduction of this paper. Many defense analysts believe that defense firms act as though increasing costs increases their profit. In the absence of any other explanations they have concluded that CPPC pricing must be the problem.

The contribution of this paper is to provide an alternative and more likely explanation as to the source of this CPPC effect.

One final remark will be noted about possible distortions involving the subcontracting decision which steps outside the bounds of the formal model of this paper. This concerns the issue of whether there will be a bias in the types of subcomponents that the firm chooses to subcontract vs. make in-house. The formal model does not address this issue because no such choice exists in the model. However, based on the analysis it is clear that such a bias will exist and could be formally modelled in a straightforward extension. Namely, for its cost-sensitive products, the firm will prefer to keep in-house those subcomponents which have high levels of direct material and labor and low levels of overhead costs. The reverse bias will exist for cost-insensitive products. In this case, subcomponents with relatively high overhead costs will be more attractive for in-house production.

The most obvious application concerns the level of automation. Products whose production is more automated will exhibit relatively higher levels of overhead costs. Therefore the prediction of this "extended model" is that a firm will bias its make/buy decision on defense products towards subcontracting subcomponents which require more automated production and making in-house subcomponents which require less automated production. The reverse bias will exist for commercial products.

Note that the result of this subcontracting bias is that defense production will be less capital intensive than commercial production. This result is closely related to the incentives for automation discussed in section D.

F. Spare Parts

A series of so-called "spare parts pricing scandals" plagued the DoD in the mid-1980s. The essential story reported was often as follows. The price of a relatively common item that individuals might buy at a hardware store was reported to be thousands of dollars in contrast to the price of perhaps ten or fifteen dollars that a hardware store might have charged.[29]

Both critics and supporters of the DoD basically agreed on the following three facts. First, the prices charged and paid generally were equal to fully allocated cost. That is, there was no sense in which defense firms were making money by charging price greater than cost. For example, Fitzgerald [1989] quotes General Ronald Yates, the F-16 program director, as providing the following explanation for spare parts prices during congressional hearings:

> "The straightforward answer is that in fact they spent the cost incurred. We knew that."[30]

Rasor [1985] quotes General Dewey Lowe as stating that

> "The items mentioned were reasonably priced in accordance with rules and regulations."[31]

Second, in some cases the high costs were partially explained by the fact that the spare part in question was much more expensive to construct than its hardware store equivalent due to different and more demanding specifications combined with small production runs. Third, in almost all cases, a very large part of the fully allocated cost was overhead allocated in the same fashion as for all of the firm's other contracts.

Of course critics and supporters of the DoD tended to differ greatly in their interpretation of these facts. First, they disagreed over the necessity of extra requirements which increased cost. This subject will not be discussed further because this paper has no new insights to offer. The second disagreement is of more interest to this paper. Supporters tended to view the fact that price equalled cost as proof there was no problem. Regarding overhead costs, they argued that overhead costs are legitimate and spare parts merely picked up their normal share. I think that it is fair to say that critics could offer no explicit intellectually sound counter argument to this view (other than to claim that overhead costs were likely inflated by "fraud waste and abuse" and thus were illegitimate costs on *all* contracts including spares).

The contribution of this paper is that it suggests an intellectually sound explanation of why the overhead allocation process might tend to create both inefficiencies and overly high prices in the procurement of spare parts. Furthermore, it is consistent with the above mentioned facts. In particular it is consistent with the fact that prices charged never exceeded fully allocated costs.

The explanation is based on the fact that spare parts contracts are likely in many cases to be very noncompetitive and thus their revenues will be highly cost sensitive. This is because they occur near the end of a program when the threat of bringing in a new source is extremely low. Furthermore government has a fairly large need for the parts in order to keep the existing fleet operative and the dollar value of the spare parts is relatively low. Thus the contracts will generally be well-funded.

Because of the highly regulated nature of the procurement process, the existence of monopoly power does not necessarily allow defense firms to charge a price greater than cost. In this particular instance it appears that defense firms generally were restricted to charge a price equal to cost.

(This is the first agreed-upon fact described above.) However, the key insight of this paper is that firms with a large degree of monopoly power will certainly be able to raise their price by a full dollar if their costs go up by a dollar. This is also consistent with the above described facts. (No one, to my knowledge, ever claimed that defense firms were forced to accept a price less than cost on the contracts under scrutiny.)

Therefore, the prediction of this paper's theory is that defense firms will have the incentive to purposely overuse direct labor on spare parts contracts in order to shift more overhead to these contracts. To the extent that this occurs this will both generate inefficiencies and raise prices.

Many of the published cost-breakdowns for spare parts are in fact mildly suggestive that this may have occurred. A very typical example is the cost breakdown reported by Rasor [1985][32] for a hammer whose price was $436. The firm purchased the hammer for $9. It then incurred direct labor costs of $130 in "handling and inspecting" the hammer. Then $240 of overhead was allocated to the hammer ($141 of M&E overhead based on direct labor and $90 of G&A based on total cost input).[33] Therefore, by incurring $130 in direct labor the firm succeeded in shifting $240 of overhead to the contract. One cannot help but wonder if the entire $130 spent on "handling and inspecting" was truly necessary or if some was incurred solely to shift overhead.

G. Dual Sourcing[34]

In weapons programs with moderately large production runs such as missiles it has become relatively common for the DoD to simultaneously purchase output from two separate suppliers. Cost data is still demanded from the firms. Furthermore, it is still audited and negotiations over price still largely revolve around cost. However, the lower cost firm is typically given a larger share of the annual buy. Quite typically the lower cost firm will receive 60 percent of the buy vs. 40 percent for the higher cost firm. Finally, there is also always the threat looming that a firm which is consistently and significantly higher cost might simply be dropped altogether. Although this situation is a far cry from a perfectly competitive market it clearly injects an extra element of competition. In terms of this paper's paradigm, dual sourcing will make a product less cost-sensitive. The stylized fact regarding dual sourcing is that it does seem to cause fully allocated costs to drop (although there is controversy over this).[35]

This paper of course supplies a theoretical explanation for this stylized fact. Dual sourcing a program is likely to make it of below average cost sensitivity. Because of this the firm will purposely underuse direct labor and eliminate all possible direct labor waste. This will result in overhead being shifted to other contracts and thus reduce fully allocated cost.

Traditional procurement analysts have typically accepted a $1 reduction in fully allocated cost due to dual sourcing as representing a $1 savings to the government. The contribution of this paper's theory is that it clearly identifies the fallacy in this interpretation. First, the bulk of cost reductions may be caused by the reallocation of overhead. If costs are reallocated to other defense contracts there is obviously no total cost savings to the government. Even if the overhead is reallocated to commercial contracts, it is not clear that the government is actually better off.[36] Second, some of the savings in direct labor cost may be caused by firms purposely choosing to use inefficiently low levels of direct labor, perhaps by overusing subcontractors. Thus not even all of the reductions in direct labor cost represent true cost savings.

Therefore, the major point of this paper regarding dual sourcing is that the existing policy debate over whether dual sourcing lowers a product's fully allocated costs or not has ignored the more fundamental questions. Suppose the DoD dual sources one product that a firm produces. There are three relevant questions to ask. These are as follows.

(i) What is the effect on fully allocated costs summed over *all* DoD products?

(ii) What is the effect on DoD payments to the firm summed over *all* DoD products?[37]

(iii) What is the effect on fully allocated costs summed over *all* of the firm's products, both DoD and commercial?

Note that question (ii) will generally be of more interest than question (i). However, to answer question (ii) one needs information on the cost-sensitivities of DoD products. Thus question (i) may generally be easier to answer. This is why it is included in the above list. Whether question (ii) or (iii) is considered to be more important depends on whether one believes that firms' profits ought to be included in a welfare analysis. This is a complicated issue and is discussed in section B of this chapter. My own sense is that question (iii) is the most important. This is because, in the long run, DoD payments to firms will only be lower if firms' costs are lower.

It is interesting to ask why the DoD uses dual sourcing so extensively if this paper's theory is true. A number of relatively mundane explanations are possible. The DoD may simply be wrong. Alternatively, even if this paper's theory is true, it may still be the case that the net effect of extra competition is to lower the firm's true total costs and lower the DoD's aggregate payments to the firm. Finally, dual sourcing may serve other goals such as maintaining reserve capacity.

However, one much more fascinating explanation also exists. This paper has focussed on the incentives of profit maximizing firms and ignored incentives within the DoD bureaucracy. However, overhead allocation has a potentially enormous incentive impact on decision makers within the DoD. In particular, individual decision makers within the DoD will generally have the incentive to try to minimize the fully allocated cost of the program or programs that they are responsible for. Thus a program manager within the DoD might quite rationally prefer to use dual sourcing if it lowered his own program's fully allocated costs simply by shifting overhead to other defense programs. At a slightly higher level, an individual military service might well prefer to use dual sourcing so long as the overhead was shifted to programs purchased by other services. Thus dual sourcing may be the result of a noncooperative overhead shifting game being played by decision makers within the DoD. The issue of incentive distortions within the DoD will be discussed further in chapter 8.

H. Effort to Reduce Direct Labor

In the formal model of this paper analyzing the firm's incentives to incur pure waste of direct labor it was assumed that the firm could effortlessly reduce direct labor to some minimum level below which it could not fall. In reality, the firm probably must devote resources towards identifying or implementing possible changes which would reduce direct labor use. As direct labor is reduced the cost of identifying further reductions increases. The purpose of this part is to simply point out that the basic results of this paper can be easily interpreted and/or extended to apply to this case as well. Namely the firm will devote too little (too much) effort towards reducing direct labor cost on cost-sensitive (cost-insensitive) contracts. Two different interpretations of the "effort" variable will be given.

Under the first interpretation, effort consists of extra management supervision or research which generates extra accounting costs allocated to overhead. This case has already been modelled in section 3F as a labor-overhead substitution and thus the desired result follows immediately.

Under the second interpretation effort once again consists of extra management supervision or research. However, in this case, existing management simply works harder or redirects its attentions. Thus, there is no change in overhead accounting costs. This case has not been formally modelled. However, it is straightforward to add an unobservable effort choice for each product where increased effort lowers direct labor cost. The result is just as expected and will simply be reported. Namely the firm devotes absolutely no effort to lowering direct labor on cost-sensitive contracts where it wants to increase direct labor. On all other contracts it devotes too much effort to reducing direct labor.

CHAPTER 7

POLICY IMPLICATIONS

A. Introduction

There are basically two possible approaches to dealing with the incentive problems described in this paper. The most promising is to increase direct cost allocation to the maximum feasible extent. This is discussed in section B. The other possible approach is to attempt to directly pay for some joint expenses on a firm-wide basis and not to allocate them to products at all. This is discussed in section C. Finally, this paper clearly raises the issue of the desirability of mixed (commercial/government) plant operations. This will be discussed in section D.

B. Maximal Direct Allocation

The defining characteristic of traditional cost accounting practices used by both defense and nondefense firms is that very little effort is devoted towards directly allocating costs.[38] Thus there are many costs currently included in overhead that could in principle be allocated directly to products. Perhaps the major policy implication of this paper is that greater efforts to directly allocate more costs would be worthwhile because the resulting decrease in overhead rates would reduce the incentive problems identified by the paper. Five remarks will now be noted about this policy approach.

First, there is sharp disagreement in the procurement community over whether increased direct allocation would be worthwhile. The predominant view is that it is not worthwhile. This is certainly the view held by industry and seems to be generally accepted by most of the DoD. The basic argument is that increased direct allocation necessarily requires increased administrative cost and there is no offsetting gain. The major dissenting voice from this view has been the DoD's own auditing group, the Defense Contract Audit Agency (DCAA) which strongly advocates maximal direct allocation. The contribution of this paper is to present an explicit theoretical reason supporting the DCAA's point of view. Lower overhead rates are of value in and of themselves because they reduce incentives for inefficient behavior.

Second, current regulations basically reflect the predominant view that there is no value to direct allocation.[39] The *CAS* makes absolutely no explicit requirement to directly allocate as many costs as possible. The closest that is comes to doing this is in *CAS* 418 which essentially requires that overhead pools be "homogenous." The DCAA has tried to argue that a pool with costs in it that could be directly allocated to different contracts is not homogenous. However, the courts have essentially determined that traditional accounting practices meet the intent of the standard. The *FAR/DFAR* comes closer to requiring this. It defines a direct cost to be a cost that *can* be allocated to single contract while the *CAS* defines a direct cost to be a cost that *is* allocated to a single contract. Once again, the DCAA has attempted to argue that the *FAR/DFAR* therefore requires maximum possible direct allocation based on the word "can." However, the courts have not agreed, based upon the interpretation that the *CAS* has primary authority regarding allocation methods and it uses the word "is," connoting that the contractor has a choice. Perhaps , as well, the courts have been unwilling to create extensive new legal requirements based on a fairly elaborate interpretation of the connotation which might be implied by one word. It is certainly the case that either the *FAR/DFAR* or *CAS* could easily have been drafted to contain a more explicit requirement if the drafters had desired to do this.

Third, it may be that the new accounting methodologies, often referred to as process-based or activity-based accounting, offer the most significant possibility for reducing overhead rates. The basic methodology involves grouping costs by machine centers and then allocating machine center costs (including all associated labor and computing costs as well as facilities costs) by machine hours of usage.[40]

Table 7.1 provides a breakdown of M&E overhead for the four aerospace firms considered in section 5.C.[41]

Table 7.1
M&E Overhead by Cost Type

Cost Type	000s of $	% of Total
Facilities related	1,124,551	48.5
Indirect labor	715,812	30.9
Data processing	225,895	9.7
Other	252,594	10.9
Total	2,318,852	100.0

Facilities related costs include the rate of return paid for facilities capital as well as depreciation, maintenance, etc. Indirect labor includes associated fringes. Data processing includes only the data processing costs charged as overhead. This is about one-third of total data processing costs, i.e., about two-thirds of total data processing costs are currently charged direct. Finally, the major items in the "other" category are travel, tools, and supplies.

The most important conclusion from this table is that the most significant reductions in overhead rates through increased direct charging would occur through direct charging of facilities capital costs. Almost half of the M&E overhead pool consists of facilities capital costs. Furthermore, it seems possible that significant amounts of both indirect labor and data processing are directly associated with operation of automated facilities rather than with any particular product. To the extent this is true it may be that direct charging of facilities would also be required to directly charge these associated costs. This is why activity- or process-based costing may be an extremely important methodology for increasing direct charging.

It is not clear, however, that process- or activity-based accounting offers a complete panacea. The reason is that at least some of the costs of machine centers are in all likelihood joint (i.e., there are economies of scope). Thus using machine hours to allocate these costs may create essentially the same problem as currently occurs when direct labor is used to allocate joint costs, i.e., firms may have the incentive to purposely overuse machine centers on their cost-sensitive contracts. This is a complex question which involves a number of theoretical and empirical issues and is beyond the scope of this paper. It requires explicit consideration of factors such as long- vs. short-run incentives, excess capacity, and whether machine hours of usage can be easily "padded" or not. I intend to explicitly study the incentive affects of process- or activity-based accounting in a future paper. A reasonable "provisional" conclusion is that it is a promising methodology but that possibly significant questions regarding it need to be investigated.

Fourth, it may be that more modest efforts to simply increase direct costing within the traditional framework may also have a significant impact. This is particularly true of efforts to increase direct charging of labor because of the double impact this has on reducing overhead and also increasing the base. For example, suppose that one-half of indirect labor could be direct charged. Using the data in tables 5.2 and 7.1 it is straightforward to calculate the new M&E overhead rate. The rate drops from .99 to .73. Thus the magnitude of the various incentive problems would be reduced by approximately 25 percent. Suppose, in addition, that one-half of the data processing and other overhead costs could also be directly charged. Then the M&E overhead rate would fall to .64.

Fifth, as industry has correctly argued, increased direct charging of costs would require greater record keeping expense. Thus prior to implementing any policy changes it would be important to attempt to estimate both the marginal costs and benefits of increased direct charging. Johnson and Kaplan [1987] argue that record keeping costs have declined dramatically because of increased use of computers. This is an empirical issue that could be fairly easily quantified.

To conclude this section, three possible policy approaches to increase direct charging will be discussed. The first is simply to create a new cost accounting standard which requires more direct costing. Although this approach superficially appears reasonable it may, if fact, exhibit some problems. In particular, because record keeping has costs, it probably is true that the optimal amount of direct charging is less than the maximum possible amount. It is not immedi--ely clear how one could structure a regulation which requires the optimal amount of direct charging. Based on historic behavior patterns, it is reasonable to conjecture that audit and enforcement agencies within the DoD might well use a regulation requiring increased direct allocation to literally require direct allocation of all possible expenses regardless of cost. The courts would then be forced to decide what level of direct allocation was required and there is no reason at all to believe that the courts would make an appropriate decision on a technical issue of this sort. A related problem is that the optimal nature and amount of direct costing might well vary from firm to firm, depending on the nature of their production processes, product mix, etc. It may be difficult to design regulations which specifically require direct costing but still allow flexibility to respond to individual circumstances.

A second policy approach designed to finesse these difficulties would be to attempt to provide firms with the incentive to charge more costs direct. Government could affect the overall level of direct costing by changing the level of incentives, but each firm could still decide the optimal nature of its own response given its individual circumstances. This could be accomplished by paying a small increment on direct costs and a small decrement on indirect costs. For example, suppose a firm charged 60 percent of its costs direct and 40 percent indirect in a given year. Then for contracts signed the next year government could purposely multiply direct cost by $(1 + x/.4)$ and multiply indirect cost by $(1 - x/.6)$ for purposes of calculating price. The value of x would probably be chosen to be quite small, perhaps .004. Thus government would add 1 percent to direct costs and subtract .67 percent from indirect costs. To the extent that the firm could charge more costs direct it would earn a small profit for one year.

The third possible policy approach involves the procedures currently in place to deal with a firm's changes in its accounting system. Under the *CAS*, a firm must file a complete description of its accounting practices with the DoD. If the firm changes any practices, it must formally report this change. At this point the DoD calculates the "cost impact" of the change on existing DoD contracts. If the costs to the DoD are calculated to rise then the firm must refund this amount to the DoD. The rules for calculating the cost impact are largely correct and will not be described here. They basically prevent contractors from "gaming" the system by changing accounting systems after they sign contracts in order to shift costs away from existing fixed price contracts onto existing cost type contracts. For the purposes of this paper the point is that it might be a reasonable policy for the government to allow one-time exceptions to this rule on a negotiated case-by-case basis for firms who want to implement major changes in their accounting systems designed to increase direct charging. This would essentially provide another financial incentive for firms to increase direct charging and remove some uncertainty associated with the change.

C. Direct Payment for Joint Expenses

The ideal accounting system would calculate direct cost for each product equal to long-run incremental cost. The remaining costs are, by definition, joint costs. The DoD's current practice is to allocate these costs to products. To the extent that these costs are allocated to defense products and to the extent that price is sensitive to accounting cost on these products, the DoD will then pay for a share of these joint costs. The major point of this section is that an alternate method of paying for these joint costs would be for the DoD to directly negotiate payments on a firm-wide basis and for no allocation to individual products to occur.

The major problem with such an approach is that there is no objectively verifiable way of disentangling many joint costs from long-run incremental costs. This problem applies to almost all joint costs occurring at the manufacturing level (as opposed to the central management level). There are probably two major sources of joint costs within the manufacturing process. The first is economies of scope. The second is excess capacity not needed for current production but which is (presumably) needed for potential future production. Both of these phenomena result in the sum of long-run incremental costs for current products being less than total cost. However, there is probably in general no objectively verifiable method for measuring either of these.

The implication of this is that the methodology of directly paying for joint expenses may only be of practical importance for G&A expenses and IR&D/B&P expenses [42] Conceptually, these are clearly joint expenses and these can be separately identified in an objectively verifiable fashion. (They already are).

Each of these two cases raise slightly different issues so each will be discussed in turn After discussing each case separately, this section will conclude by estimating the change in incentives which would occur if both these costs were directly paid.

(i) G&A

Under the proposed method, prior to the beginning of each year, DoD representatives and the firm would agree to a contract governing the firm's

G&A reimbursements for the upcoming year. Payments would be made directly to the firm and not be attached to any product. The contract could be a "fixed price" contract or involve some cost sharing. It may be that G&A expenses are predictable enough that a fixed price type arrangement where government makes a fixed direct payment regardless of *ex post* costs would be desirable.

A major problem which may limit the effect of this change regards how the DoD will determine the share of the G&A it is willing to pay when the firm has both government and commercial business. The inevitable tendency (and perhaps the only possible solution) might be for the DoD to pay for a share equal to its share of the firm's total business. Of course there is no way to measure this other than by using the share of direct labor or total cost input employed on DoD contracts. The problem with this is that it preserves precisely the incentives which are not wanted. Namely, the firm can increase the share of its G&A which is reimbursed by engaging in input distortions.

Two remarks should be noted about this problem. First it does not mean that direct payment of joint costs will have no desirable effects. Many of the undesirable incentives of the current system are created by firms' attempts to shift overhead between defense contracts. All of these problems would be solved. Second, one possible solution for firms with only "moderate" levels of commercial business would be for government to simply view 100 percent of the G&A expenses as legitimate costs. One possible related policy change could be to require firms to exclude purely commercial expenses from the G&A pool (such as commercial selling expenses). It may be that, on average, 100 percent of the remaining expenses is approximately equal to the DoD's previous share of total G&A. No publicly available data is available on this issue but it could obviously be gathered.

The major danger of adopting the policy of direct payment for G&A is that this somehow might cause the DoD to decide to quit paying for it. In the short run the DoD could probably pay for no G&A and still purchase the weapons it desires. However, in the long run, firms stay in business only if all of their joint costs can be covered. The proposed system would require separate appropriations for G&A expenses. Perhaps there would be a danger that either Congress or the DoD itself would somehow then be more tempted to not pay for these "unproductive" costs. The fact that there might be no short-run consequences would increase the danger. The current system does not allow the DoD or Congress to easily single out G&A expenses. Whether this "protective linkage" with all other costs is truly desirable or not is not clear. However, it is an important issue which would need to be considered before implementing this change.

(ii) IR&D/B&P

Independent research and development (IR&D) expenditures are expenditures on research and development independently conducted by the firm (i.e., not required by any contract) and for which the firm receives all resulting patent rights, etc. Bid and proposal (B&P) expenditures consist of expenditures by the firm in preparing, submitting, and supporting bids and proposals on government and nongovernment contracts.

The current procedure for government subsidization of these expenditures is basically as follows.[43] Prior to the beginning of each year the DoD negotiates an IR&D/B&P ceiling with each firm. Then in the upcoming year IR&D/B&P expenditures up to the ceiling level are considered as legitimate costs for purposes of government contract pricing. The IR&D/B&P costs are allocated to individual contracts using the same allocation base as G&A.

For example, suppose that a ceiling of $1 million is negotiated with a firm. During the year the firm spends $1.5 million on IR&D/B&P and 70 percent of its total cost input is for DoD business. Then 70 percent of $1 million, or $700,000 will be allocated to DoD contracts. The firm will recover some share of the $700,000 depending on the cost-sensitivity of its contracts. Note that in general it is probably not known with any precision what fraction of the $700,000 the firm actually receives. Furthermore, the fraction recovered may vary widely from firm to firm or from year to year within the same firm.

The policy approach suggested by this paper is to replace this procedure with a subsidy paid directly to the firm and negotiated at the start of each year. For example, the DoD might agree to pay 70 percent of the first $1 million of expenditures of the firm. Then over the year the DoD would directly pay the firm 70¢ every time that $1 of IR&D/B&P expense was incurred until $1 million of expenditures were incurred. One could obviously imagine more complicated variants. The result of th policy change would be that overhead rates would decrease and thus the incentive problems identified by this paper would diminish.

Four remarks will now be noted about this policy approach. First, directly paying for IR&D/B&P is a vastly superior method to that currently used even if one ignores the effect on overhead rates. This is because the current convoluted process makes it almost impossible to know how much of a subsidy is being paid to any particular firm. Furthermore, the subsidy will vary in uncontrollable ways among firms and within the same firm over time. A system which allowed one to explicitly choose both the marginal rate of subsidy and the total subsidy offers obvious advantages.

Second, the only possible advantage of the current system is that it may result in less Congressional and/or DoD influence on firms' decisions as to what types of programs to undertake. One of the rationales for IR&D subsidies is to encourage firms to independently develop their own approaches and ideas without excessive government guidance and thus generate a wider variety of research than if the DoD directly funded all R&D through contracts. Thus one might argue that increasing Congressional or DoD influence would be negative. The reason that the current system may result in less Congressional or DoD influence is that no money is ever actually appropriated or directly paid for IR&D. One might argue that if Congress began appropriating money directly for subsidies that more oversight and formal reporting requirements would be the inevitable result This argument is suggested by Alexander, Hill, and Bodilly [1989].[44] However, it is by no means clear that this argument is valid. In principle, exactly the same level of independence could be maintained. Furthermore, Congress has to approve the annual ceiling levels of IR&D/B&P under the current system and the DoD directly negotiates the ceilings. It is not clear why the opportunities for control would be that much greater under a subsidy system. In conclusion, there is only one possible disadvantage to adopting the proposed policy approach and it is by no means clear that it would be significant.

Third, the problem raised for the G&A case of determining an appropriate share for the DoD to pay when the firm engages in both government and commercial business does not arise. Regarding IR&D expenditures, DoD personnel already evaluate proposed research projects for potential military relevance when deciding how large a ceiling to negotiate with each firm. Regarding B&P expenditures, the obvious solution would be to only include B&P expenditures on DoD programs. Thus there is no reason for the DoD to attempt to base payments for IR&D/B&P on the share of total cost input employed on DoD contracts.

Fourth, there is currently a very large policy controversy over whether IR&D/B&P subsidies are too large or not. The debate focusses on whether, and to what extent, these subsidies cause firms to increase their research expenditures.[45] This debate is basically on a different issue than that considered by this paper. The debate is over the appropriate size for the total and marginal subsidy to IR&D/B&P. The point of this paper is that given any desired total and marginal subsidy, it is optimally given to firms through direct payments instead of through overhead pools.

(iii) **Magnitude of Incentives**

This part will calculate the change in overhead rates that would occur if IR&D/B&P and/or G&A were directly paid. The calculations will be made using the data for the four aerospace firms as presented in chapter 5 and appendix E. From table 5.2, G&A/IR&D/B&P expenditures were 8.1 percent of total cost. From appendix E, table E.7, this can be broken down into G&A expenditures of 5.6 percent and IR&D/B&P expenditures of 2.5 percent.

It is straightforward to calculate new values of D if one or both of these two expenditures were paid directly. These are presented in table 7.2. Recall that D is the number of dollars of overhead shifted by one dollar of direct labor. Reductions in D essentially cause proportionate reductions in the magnitude of incentives to distort direct labor.

Table 7.2
Values of D if G&A and/or IR&D/B&P Were Directly Paid

Case	Value of D
Neither directly paid	1.17
IR&D/B&P directly paid	1.10
G&A directly paid	1.04
Both directly paid	.99

The major conclusion to be drawn from table 7.2 is that direct payment for G&A and/or IR&D/B&P would have only a moderate impact on the magnitude of incentive distortions. Direct payment of both costs would reduce D from 1.17 to .99 which is a 15 percent reduction. This mild reduction reflects the fact that most overhead is in the M&E pool, and that G&A/IR&D/B&P is allocated over total cost input which reduces distortionary incentives.

D. Mixed Plant Operations

Many large defense contractors are extremely large diversified companies with multiple divisions engaged in different types of business. Each division is typically a separate accounting entity. Production of products for the DoD will typically be concentrated in one or more "government products" divisions. However, many defense firms will typically produce at least some commercial products within their government products divisions. In its last major statistical survey of defense contractors, the DoD found that government products divisions of major defense contractors averaged 82.8 percent DoD business and 17.2 percent commercial business.[46] This figure can vary widely between firms. General Dynamics, for example, produces almost entirely DoD products. Boeing, on the other hand, produces significant amounts of both defense and commercial products within the same divisions of the company.

A correct conclusion to draw from this paper is that the incentive to increase direct labor use on DoD contracts will be greater when the amount of commercial business within a division increases. If this was the only effect of mixing government and commercial business then it would follow that government ought to discourage this practice. However, there are probably a number of relatively large advantages to this mixing of business types and it may well be that the advantages outweigh the disadvantages. Attempting to make this evaluation is beyond the scope of this paper. The point being made here is simply that it is by no means clear that government ought to discourage mixed plant operations. It may be that the optimal policy is o encourage or at least allow mixed plant operations and to pursue the other policy approaches outlined above to ameliorate the undesirable incentive effects.

To conclude this part, possible advantages of mixed plant operations will be briefly listed. First there may well be economies of scope and scale which can be taken advantage of. One often-cited economy of scope is based on the fact that defense and commercial business demand is often uncorrelated. Thus, by engaging in both, a firm may be able to smooth input usage and produce at lower cost. Second, it is often argued that incentives to operate efficiently generated by commercial activities can spill over into a firm's defense work. Third, it may be that productive capacity employed on commercial production within a government products division may be more easily switched to DoD production than would productive capacity in a purely commercial division. If so, mixed plant operations might create reserve capacity for DoD production.

CHAPTER 8

DISTORTIONS IN DoD DECISION MAKING

The focus of this paper has been on distortions in defense firms' decision making. However, current overhead allocation practices will also tend to distort internal decision making within the DoD. The purpose of this final chapter is to very briefly explain why this is so. I intend to analyze this issue more thoroughly in a future paper. However, an important preliminary conclusion which is drawn below is that the two policy approaches suggested in chapter 7 (greater direct costing; direct payment for joint costs) will also tend to ameliorate incentive distortions within the DoD bureaucracy.

The basic reason that current overhead allocation practices distort internal DoD decision making is that individual decision makers within the DoD will generally have the incentive to try and minimize the fully allocated cost of the program or programs that they are responsible for. However, this will in general not minimize the cost to the entire DoD. This is because one very effective way to minimize the fully allocated cost of a program is to shift overhead to other programs. Thus individual program managers will value cost reductions which arise solely because overhead is shifted to other programs. Military services will value cost reductions caused by overhead shifting so long as the overhead is shifted to programs purchased by a different service. Thus individual decision makers within the DoD may to some extent be involved in a noncooperative overhead-shifting game.

One important example of this phenomena may be dual sourcing. This was discussed in section 6G. Another example concerns the decision of a program manager as to which costs to monitor most closely. He will obviously have a disproportionately large incentive to monitor direct labor costs as opposed to costs accumulated in overhead pools. Finally, individual program managers or services may avoid placing contracts with firms exhibiting a large amount of excess capacity desired by some other program manager or service.

There are two different approaches to solving this problem. The first is to reduce the incentives of individuals to make distorted decisions. It is clear that greater direct costing and greater direct payment of joint expenses will tend to accomplish this.

The second approach is to attempt to institute procedures which allow more centralized oversight. The source of the problem is that decision makers at lower levels may not fully internalize the effects of their decisions on other parts of the organization. Thus one possible solution would be for central authorities (who internalize more of these external effects) to exercise more oversight. Of course complete oversight is impossible. This is why delegation occurs in the first place. Nevertheless, oversight has some effect and its effect is likely to be greater if it is easier for central authorities to gather, process, and understand the relevant information. It is fair to say that central decision makers in the DoD or Congress rarely are presented with any data other than fully allocated accounting cost. Thus greater direct costing would improve the situation because fully allocated cost would tend to be closer to long-run incremental cost. However, more radical changes in the form of budget information which made the nature of the external effects more transparent might also be useful.

Finally, it should be noted that the issues raised in this chapter are very analogous to those raised by proponents of activity- or process-based accounting for commercial firms.[47] A commercial firm is a large complex bureaucracy much as the DoD is. Thus the same two problems of distorted incentives and inadequate information for central authorities arise. Increased direct costing is seen as a solution to both these problems for the same reasons as for the DoD case.