Logistics Management Institute

On the Use of Transfer Prices Within DoD

The Case of Repair and Maintenance of Depot-Level Reparables by the Air Force

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Preface

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Abstract

Each year, approximately $81 billion of supply and logistics services are bought and sold in internal Department of Defense (DoD) markets. Supply and logistics agencies within DoD are generally run as self-supporting business units. They sell their goods and services to DoD customers and charge prices that allow them to break even. Setting prices according to the break-even principle creates a "neat and tidy" funding system for supply and logistics organizations. However, it is inconsistent with the primary role that transfer prices are supposed to play in an organization. This is encouraging users of internally supplied inputs to make efficient decisions by making them aware of and responsible for the cost of producing these inputs. In order to accomplish this function, transfer prices must be set equal to marginal cost, and the break-even principle is neither necessary nor sufficient for marginal cost pricing. Incorrect pricing results in significant inefficiencies in resource allocation decisions. This paper considers the case of repair and maintenance of aircraft components by the Air Force. It provides a specific and detailed analysis of pricing errors in this system, the distortions in decision-making that these errors induce, and specific detailed recommendations for fixing these errors. More generally, it provides an illustration of the types of pricing errors occurring throughout DoD's internal markets for supply and logistics services, and how these could be corrected.

On the Use of Transfer Prices Within DoD:
The Case of Repair and Maintenance of Depot-Level Reparables by the Air Force

EXECUTIVE SUMMARY

In some cases, military units directly purchase supplies or services from private commercial firms. However, the vast majority of such items are supplied to military units by other organizations within DoD. Even for simple consumables such as fuel, purchasing, inventory management, and other logistical functions typically are handled by central logistics organizations to capture various economies of scale and scope. A significant amount of off-base repair and maintenance is also provided by government owned and operated repair depots. Supply and logistics organizations within DoD are the analogues of what are usually referred to as "service centers" within large commercial firms. These are divisions within the firm that produce outputs that are consumed by other units of the firm instead of outputs that are directly sold to customers.

The typical concern of top management in such situations is that the users of internally supplied inputs are motivated to make efficient use of those inputs given the cost to the firm of producing them. A related concern is that suppliers of internally supplied inputs are motivated to supply those inputs as efficiently as possible. The standard solution in commercial firms is to use internal transfer prices. Under this arrangement, the service center sets a "price" for each input that it produces equal to the cost of producing it. Users of the internally supplied input must "purchase" inputs from the service center just as they purchase inputs from outside suppliers. Since customer divisions pay a price equal to the cost of producing the input, they are encouraged to make efficient use of the input.

Service center pricing is not to determine whether service centers should exist. It is to ensure efficient use of the outputs of those service centers. Decisions on the existence of service centers are made on other considerations and demand other information.

The DoD faces the analogous problem for its supply and logistics organizations. Not surprisingly, it has turned to the same solution used by private firms. Although it has always made some use of internal transfer prices, a series of reforms instituted in the last five years, with the goal of making DoD more "businesslike," has resulted in much more widespread use of transfer prices. The group of all supply and logistics organizations within DoD that sell their outputs to other organizations within DoD is now known as the Defense Business Operations Fund (DBOF). In 1993, organizations within DBOF had sales equal to $81

billion, which is approximately equal to one-third of the defense budget (GAO 1992). Thus, an enormous share of the total resources controlled by DoD is now allocated through internal transfer prices.

For transfer prices to perform their job, each price must be set equal to the cost to the organization of producing each internally supplied input. If prices are set differently, they will communicate the wrong information through the organization and incorrect decisions will be made. The major purpose of this paper is to argue that DoD's use of transfer prices has not achieved all the efficiencies it is capable of because DoD has not followed the basic principle of setting prices equal to cost.

The relevant cost of an internally supplied input to an organization is its ***marginal*** cost (i.e., the extra cost that the organization will incur if it produces the input versus if it does not produce the input). Rather than attempting to set prices equal to marginal cost, DoD has followed a practice that can be referred to as the "break-even principle." This principle comes from viewing transfer pricing as primarily a funding device rather than a device for decentralizing decisions. Under this principle, a service center must identify products and charge prices for them so that its total revenue equals its total cost. Thus, instead of being funded by appropriations, it is funded by revenues earned from customers. The main goal of this principle has probably always been to create a "neat and tidy" funding system. However, it does not induce users of internally supplied inputs to make correct decisions. Breaking even is neither necessary nor sufficient for prices to equal marginal costs, which is the rule that induces correct decisions. This has resulted in three major types of pricing errors.

In order to provide a more concrete analysis of these issues, we focus on one specific supply and logistics function within DoD where these problems appear to be quite significant. This is repair and maintenance of depot-level reparables (DLRs) by the Air Force. A military aircraft is designed as a series of replaceable components. When a malfunction occurs, the component that malfunctioned is removed at the flight line and immediately replaced by a functioning component from a locally available inventory of functioning spares. Then, the issue of what to do with the broken component can be addressed. Some repairs are accomplished on base by the military units themselves. However, more complex repairs requiring specialized equipment are often performed in central repair depots owned and operated by the Air Force. Regardless of where repair occurs, all of these components are generally referred to as depot-level reparables.

Individual military units can be viewed as the "user divisions" in this situation. The "service center" is the entire supply system for DLRs, which consists of two parts, a central logistics agency and a number of Air Force-owned and operated repair depots. The supply system provides two services to military units. First, it supplies access to inventories or inventory maintenance. Central logistics is the owner and manager of all inventories of functioning DLRs; one of its jobs is to maintain an adequate supply of inventories available for each military unit. Second, in the event that the military unit decides not to repair a broken DLR itself, the supply system arranges a repair. The military unit simply turns the

broken component over to central logistics, which arranges to repair the component at a depot.

The main decision that transfer prices influence is the "location of repair" decision. When a DLR malfunctions and is removed from the aircraft, should the military unit repair the component itself or should it turn the broken unit over to central logistics for repair?

Prior to 1991, transfer prices were not used in the relationship between military units and the supply system. The supply system was directly funded through appropriations and military units simply requisitioned services from the supply system as necessary. A set of regulations, at least in principle, described how the military units should make the location of repair decision for every possible malfunction of every possible DLR. The problem with this system was that regulations could not possibly describe all possible states of the world and that circumstances varied from base to base. Thus, in all likelihood, the location of repair decision was often being made incorrectly (i.e., military units were performing some repairs on base that could be more cheaply performed at the depot and vice versa).

In 1991, the Air Force responded to this problem by implementing a transfer pricing system. The supply system was turned into a service center operating under the break-even principle. Let n denote the number of types of DLRs used by the Air Force. Then the service center was decreed to produce n marketed products where product i was the repair of DLR type i. An accounting system was established that allocated all of the costs of the supply system for reparables to one of these products, and the price of product i was set equal to its accounting cost. Military units received appropriations to fund repair and maintenance of DLRs and could choose to purchase repair from the supply system or to engage in on-base repair themselves. The theory, of course, was that, so long as prices of repairs were set equal to the actual cost to the supply system of performing repairs, then military units would compare prices charged by supply to their own on-base costs and automatically make the location of repair decision that was cost minimizing from the perspective of the Air Force as a whole.

The new system was not fully implemented until 1993. Furthermore, we suspect that insufficient time has elapsed to appropriately observe the long-run response of military units to this system. Nonetheless, there are some indications that behavior may be responding quite dramatically to the new system, and the nature of the response appears troubling to at least some observers. In particular, it appears that military units and the commands above them are responding to this price system by attempting to shift large amounts of repair to the base level that were formerly done at the depot level. This is troubling, because according to analysis it has done itself, the Air Force believes that many of these repairs should have been performed at the depot level in order to minimize costs to the Air Force as a whole. [See Camm and Schulman (1994) and Glass (1994) for a discussion of this.]

What has gone wrong? The answer appears to be that the Air Force has simply set the wrong prices. Prices set under the break-even principle have generally been significantly different than marginal costs. Thus, military units and commands above them have been making good decisions given the information that prices have communicated to them. The problem is that the information prices communicated have been seriously flawed.

Three major pricing errors have occurred. The first pricing error is the failure to recognize that the supply system provides two different services to military units. Regardless of where repair occurs, a military unit always relies on the supply system for access to an inventory of functioning spares to replace the malfunctioning component while it is repaired. Thus, the supply system provides access to inventories as well as to repair. Under the current system, costs of the supply system for reparables are allocated to repair. Thus, a military unit is essentially told that if it decides to perform a repair on base, it can have access to inventories for free. However, if it decides to ask the supply system for repair, it must pay for both repair and the entire cost of maintaining access to inventories. Prices of repair would be lower by 28 percent if these costs were not allocated to repair.

The second pricing error concerns the treatment of the cost of replacement. An extra fee is added onto the cost of all depot repairs to recover the cost of purchasing new items to replace those that wear out. Replacements are provided free of any extra charge to military units, when needed. Thus, essentially the same type of situation occurs as described above. Military units are told that if they choose to repair a component on base, they do not have to help pay for replacement costs. However, if they choose to ask for a depot repair, they must make such a contribution. Once again, the result is that depot repair is priced above the cost of providing depot repair. Prices would be lower by 23 percent if this cost was not added onto the cost of depot repair.

Taking the first two pricing errors together, prices would be lower by 51 percent if these costs were excluded. To put this another way, on average, the supply system has been charging twice as much for a depot repair as it actually costs the system to produce a repair. In light of this, the decision of military units to avoid purchasing depot repairs seems less surprising.

The third pricing error is somewhat different. The supply system has set a single repair price for each DLR type, which does not vary according to the nature of the malfunction of the DLR. Thus, the supply system charges the same price for easy repairs as for difficult repairs. The completely unsurprising result of this has been that military units have begun to perform repairs of below average difficulty on base, even if they could be performed more cheaply at the depot. The reason is that the supply system does not offer to do the easy repair for a price equal to the actual cost of performing the easy repair. It sets a much higher price equal to its cost of performing a more difficult repair.

We suspect that part of what we have been observing over the last two or three years is a series of initial iterations toward a new long-run equilibrium that

may be much worse than what has been seen yet. In its first year of operation, the supply system set an average price for repair under the assumption that it would continue to do the same types of repairs as in past years. The unpleasant surprise it received was that many of the easy repairs migrated over to the bases, resulting in a higher average cost of repair than anticipated. Thus, in year two, the supply system set new, higher prices to reflect last year's unpleasant surprise. Of course, the result of higher prices in year two was a new unpleasant surprise. Even more easy repairs migrated over to the bases, which caused the average cost of a depot repair to become even higher. This will cause a new price adjustment, which will induce a new migration, and so on. Where this process will reach equilibrium is not yet clear.

The major outlines of the solution to this problem are conceptually simple. All central logistics costs (except for some minor items that clearly vary with repair, such as transportation) should be funded by having the supply system directly charge annual fees to higher elements within the Air Force organization (such as commands or central authorities themselves), which do not depend on consumption of depot level repairs. Costs of replacement should be funded by annual charges to military units on the basis of the number of DLRs employed (i.e., a military unit employing 5 percent of the aircraft of a particular type should pay 5 percent of the estimated replacement costs for DLRs belonging to that aircraft). Finally, the supply system must take some steps toward improving its internal information systems so that it can begin to keep track of what is done to individual DLRs, which would allow repair charges to reflect the difficulty of the repair that was actually accomplished.

The idea that internal transfer prices can be used to decentralize and thus improve "location of repair decisions" is a good one. Furthermore, the observation that military units apparently do respond to prices supports its plausibility. The major problem is that prices have not been set equal to the cost to the supply system of providing depot repairs. However, this problem appears to be fairly easy to fix conceptually. Therefore, a revised set of transfer pricing practices might well be a useful device to help the Air Force improve its decision-making. However, the errors being made by current pricing practices are likely to result in major errors in decision-making. Thus, revising its transfer pricing rules should be a top priority for the Air Force.

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CHAPTER 1

Introduction

GENERAL

In some cases, military units directly purchase supplies or services from private commercial firms. However, the vast majority of such items are supplied to military units by other organizations within DoD. Even for simple consumables such as fuel, the purchasing, inventory management, and other logistical functions for these goods are typically handled by central logistics organizations to capture various economies of scale and scope. A significant amount of off-base repair and maintenance is also provided by government-owned and operated repair depots. Supply and logistics organizations within DoD are the analogues of what are usually referred to as "service centers" within large commercial firms. These are divisions within the firm that produce outputs that are consumed by other units of the firm instead of outputs that are directly sold to customers. The typical concern of top management in such situations is that the users of internally supplied inputs need to be motivated to make efficient use of these inputs, given the cost to the firm of producing them. A related concern is that suppliers of internally supplied inputs must be motivated to supply these inputs in as efficient a way as possible.

The standard solution in commercial firms is to use internal transfer prices [Kaplan (1982), Kovac and Troy (1982), Magee (1986)]. Under this arrangement, the service center sets a "price" for each input that it produces equal to the cost of producing it. Users of the internally supplied input must "purchase" inputs from the service center just as they purchase inputs from outside suppliers. Since customer divisions pay a price equal to the cost of producing the input, this encourages them to make efficient use of the input. It is also often argued that because user divisions are made directly aware of the cost of internally supplied inputs, there is more pressure on supplier divisions to keep costs low.

DoD faces the analogous problem for its supply and logistics organizations. Not surprisingly, it has turned to the same solution used by private firms. Although it has always made some use of internal transfer prices, a series of reforms instituted in the last five years, with the goal of making DoD more "businesslike," has resulted in much more widespread use of transfer prices. The group of all supply and logistics organizations within DoD that sell their outputs to other organizations within DoD is now known as the Defense Business Operations Fund (DBOF). In 1993, organizations within DBOF had sales equal to $81 billion, which is approximately equal to one-third of the defense budget (GAO 1992). Thus, an enormous share of the total resources controlled by DoD is now allocated through internal transfer prices.

In order for transfer prices to perform their job, it is clear that each price must be set equal to the cost to the organization of producing each internally supplied input. If prices are set differently, they will communicate the wrong information through the organization and incorrect decisions will be made. The major purpose of this paper is to argue that DoD's use of transfer prices has not achieved all the efficiencies it is capable of because DoD has not followed the basic principle of setting prices equal to cost.

The relevant cost of an internally supplied input to an organization is its ***marginal*** cost (i.e., the extra cost that the organization will incur if it produces the input vsersus if it does not produce the input). Rather than attempting to set prices equal to marginal cost, DoD has followed a practice that can be referred to as the "break-even principle." This principle comes from viewing transfer pricing as primarily a funding device rather than a device for decentralizing decisions. Under this principle, a service center must identify products and charge prices for them so that its total revenue equals its total cost. Thus, instead of being funded by appropriations, it is funded by revenues earned from customers. In practice, this is implemented in three steps.

1. A set of outputs that will be marketed is selected. Not all of the outputs of a service center can or should be sold on internal markets. For example, some outputs are intangible or difficult to measure.

2. An accounting system is developed such that all costs of the service center are allocated to units of the marketed outputs. In many cases, very little attention is devoted to "correctly" allocating costs.[1] The main goal is to fully allocate costs.

3. Prices are set equal to fully allocated accounting costs. By construction, these prices cause the service center to break even.

The main goal of this principle has probably always been to create a "neat and tidy" funding system. However, it does not induce users of internally supplied inputs to make correct decisions. Breaking even is neither necessary nor sufficient for prices to equal marginal costs, which is the rule that induces correct decisions. This has resulted in three major types of pricing errors.

First, under the break-even principle, users of the marketed outputs end up paying prices that include the cost of producing nonmarketed outputs. Thus, prices of the marketed outputs are higher than their true production costs and users under-consume them. Second, fixed costs of production (i.e., costs that do not vary with production of any output) are included in the price of marketed outputs. Once again, this causes prices to rise above marginal cost; thus, users under-consume the marketed goods. Third, even within the pool of costs that vary with marketed outputs, DoD has devoted insufficient attention to guaranteeing that costs are correctly assigned to products. So long as prices are "on

[1] Of course, carefully defining what is "correct" is the purpose of this paper. Here, we use the term "correct" more in the general accounting sense of attempting to allocate costs that are clearly variable to the products generating those costs.

average" correct (in the sense that total revenue equals total cost), whether or not revenue earned on a particular product equals the cost of producing that particular product has not been of major concern. This results in prices communicating incorrect information about individual products.

In order to provide a more concrete analysis of these issues, this paper will focus on one specific supply and logistics function within DoD where these problems appear to be quite significant. This is repair and maintenance of depot-level reparables (DLRs) by the Air Force. Although we have not examined pricing practices in other areas of supply and logistics in as great a detail, it appears that problems similar to those identified in this particular area exist throughout the DBOF. Thus, one can read this paper in one of two ways. First, it provides a fairly specific and detailed analysis of pricing errors in the Air Force DLR system, the distortions in decision-making that these errors induce, and specific detailed recommendations for fixing these errors. Second, the paper illustrates the types of pricing errors occurring throughout DBOF and how these can be corrected.

Related Literature and Organization of the Paper

The basic idea that transfer prices and internal markets can be used to help organizations make decisions is, of course, well recognized [Johnson and Kaplan (1987), Kaplan (1982), Kovac and Troy (1989), Magee (1986)]. Camm and Schulman (1994) and Glass (1994) both make the point that this theory is relevant to analyzing how prices should be set for the repair of aircraft components. They raise many of the issues that are analyzed in this paper. The main contribution of this paper is to provide a systematic analysis of the entire problem from an economic perspective.

Chapter 2 explains why setting price equal to marginal cost induces good decisions. Chapter 3 provides background information about the Air Force's DLR supply system. Chapter 4 describes pricing errors of the current system due to nonmarketed outputs and fixed costs and how they should be fixed. Chapter 5 discusses other pricing errors and the impact of nonfungible budget allocations on the decision-making of military units. Finally, Chapter 6 summarizes the major policy recommendations of this paper for the Air Force DLR system and speculates about how these conclusions may apply more generally to the DBOF.

CHAPTER 2

Marginal Cost Pricing

This chapter explains why setting transfer prices at marginal cost induces users of internally supplied inputs to make efficient decisions. It will also describe three basic pricing principles that follow from the marginal cost pricing rule.

THE BASIC IDEA

Suppose that a service center produces n marketed outputs. That is, there are n different products that the service center produces and sells to user divisions within the organization. Let x_i denote the number of units the service center produces of product i for $i \in \{1, \ldots, n\}$. The service center may also produce some non-marketed outputs. These are outputs that are supplied "free" to user divisions within the organization, in the sense that they are not priced. Central authorities within the organization directly regulate the production and consumption of these nonmarketed outputs.[1] Suppose that the service center produces m nonmarketed outputs indexed by $i \in \{n+1, \ldots, n+m\}$; once again, let x_i denote the number of units the service center produces of nonmarketed product i.

Assume that the costs of producing these products is given by

$$C = F + \sum_{i=1}^{n+m} c_i x_i .$$

The assumption of linearity is made basically for expositional convenience and does not affect the main conclusions of the paper. The amount F is usually referred to as the fixed cost, since it does not vary with volume of production. The amount $c_i x_i$ is usually called the variable cost of product i since this cost varies with production of product i. The marginal cost of product i is defined to be the cost of producing one more unit of product i. In the above linear case, the marginal cost of product i is c_i.

Now, consider a simple resource usage decision by one of the user divisions. Suppose that it decides to undertake a new activity and there are two alternatives it can use. Under one alternative, the user division would use z more units of marketed product i from the service center. Under the second alternative, the

[1] There are several reasons why central authorities may choose to have some outputs of the service center remain nonmarketed. For example, some outputs are intangible and are thus difficult or impossible to measure. In other cases, the output has a "public goods" aspect (i.e., it simultaneously benefits multiple users within the firm).

user division would spend D dollars on an alternative input purchased from outside the firm. In all other respects, the alternatives are identical. Which should the user division choose?

From the standpoint of the organization as a whole, this is a relatively simple calculation. The cost of external supply is D. The cost of internal supply is the extra cost that the organization would incur by producing z more units of product i. This, by definition, is the marginal cost times the number of units produced, or $c_i z$. The user division should choose the cheapest alternative. That is, it should follow the rule

$$\text{Choose Internal Supply} \Leftrightarrow c_i z < D.$$

Now, suppose that the internal transfer price of good i is p_i. From its own perspective, the user division views the cost of external supply as D and the cost of internal supply as $p_i z$. It will choose the cheapest alternative from its own perspective. That is, it will follow the rule

$$\text{Choose Internal Supply} \Leftrightarrow p_i z < D.$$

By comparing the two rules above, it is immediately apparent that the user division will always make the decision that is correct from the standpoint of the organization as a whole if price is set equal to marginal cost (i.e., if $p_i = c_i$). The reason for this is very simple. The user division views the transfer price, p_i, as the per unit cost of product i. The true cost of product i is its marginal cost, c_i. Therefore, if price is set equal to marginal cost, the user division will correctly perceive the cost of internal production. Thus, the role of transfer prices is essentially to communicate information about marginal cost throughout the organization.

The major qualitative features of the marginal cost pricing rule can be summarized in the three principles described below.

Principle #1: Do not Allocate Fixed Costs

Fully allocated accounting cost includes a share of the fixed costs, F. This will cause p_i to rise above c_i and thus induce user divisions to view product i as more expensive to produce than it really is. The result will be that, in some circumstances, user divisions will choose not to use internal supply when this would actually have been the cheapest alternative from the standpoint of the organization as a whole.

A numerical example may help make this point more clearly. Suppose that the marginal cost of providing a product is $1,000. However, once fixed costs are allocated, the accounting cost is $2,000. Suppose that a user division needs to purchase one more unit of the input to accomplish some task. Alternatively, it could spend $1,800 on a commercially available substitute. Although the

accounting cost is $2,000, the true cost to the organization of providing one more unit is the marginal cost, $1,000. Therefore, the organization as a whole would be $800 worse off if the user division used external supply. What transfer price induces the user division to correctly make this calculation? If price is set equal to $2,000, the user division will feel it can save $200 by using external supply and will presumably choose to do so. If price is set equal to marginal cost, $1,000, the user division will feel it can save $800 by using internal supply, which is the correct calculation.

In a sense, the effect of including fixed costs in price can be viewed as analogous to the effects of a distortionary tax. Users are being told that, in addition to the variable costs of producing the output they demand, they will also be required to pay for a share of the fixed costs that are used to support the entire system. The problem with this approach is that the share of the fixed cost that a user pays for is made proportional to the amount of output he or she consumes. This essentially means that users can avoid the tax by reducing their consumption. Thus, when fixed costs are included in price, users are essentially being told that fixed costs can be avoided by reducing output. However, from the standpoint of the organization as a whole, this is not true, and telling users that they can reduce fixed costs by avoiding consumption communicates the wrong information to them. The result is that users will consume less internal input than would be efficient form the standpoint of the organization as a whole.

Once it has been agreed upon that fixed costs should not be allocated, two interesting questions arise. The first is how to treat costs that are fixed in the short run but variable in the long run. The main example of such costs is the costs associated with long-lived physical capital. At a theoretical level, the issue of whether such costs should be included in prices is not well understood. In practice, such costs are often allocated to products. The reason for this is that, at least in practice, long run decisions are often not explicitly made by the organization. Rather, they are simply the result of a series of short-term decisions. The intuition, then, is that if users do not have to pay for the cost of physical assets used to produce a product, they will demand too much each year, and thus, in the long run too much will also be demanded.

Contributing to the general analysis of this issue is beyond the scope of this paper. Furthermore, the more significant issue for the case of the Air Force DLR system is that costs that are fixed, even in the long run, are being allocated. Finally, in the Air Force DLR system, the method by which physical assets are currently funded is actually quite complex; explaining and analyzing it would require a paper of its own. Therefore, we will essentially set this issue aside for the purposes of this paper by only considering costs to be fixed if they are fixed in the long run as well as in the short run. Thus, for the purposes of this paper, the existence of fixed costs is synonymous with economists' notions of long run economies of scale and scope.

The second question that arises is that if users do not pay for fixed costs through prices on marketed outputs, who should pay for these costs and how? One possibility would be not to require the service center to break even.

However, if it was thought desirable, it would be possible to maintain the feature that the service center breaks even through revenues earned from users. This could be done by having a service center charge fixed annual fees to users to recover its fixed costs. It will be argued that this alternative may present some advantages for the case considered by this paper.

Principle #2: Do not Allocate the Costs of Nonmarketed Outputs to Marketed Outputs

Under the break-even principle, the service center is required to recover ***all*** of its costs from revenues earned on marketed products. In particular, if the service center is producing some products that it provides for "free" in the sense that it does not charge a price for them, then the costs of producing these nonmarketed outputs will be allocated to marketed outputs. From the standpoint of the marketed outputs, the cost of producing nonmarketed outputs is simply another type of fixed cost (i.e., it is a cost that must be incurred regardless of whether the marketed output is produced). Therefore, precisely the same point applies. Namely, this cost should not be allocated to marketed outputs.

The only difference in this case concerns the question of who should pay for these costs. In this case, the immediate question to ask is whether it would be possible and desirable to turn the nonmarketed good into a marketed good (i.e., to measure its usage and charge a price to users on the basis of measured usage). If this is not possible or desirable, then the same remark applies as for fixed costs. If it is desired for users to pay for these costs, they must be recovered by fixed annual fees that do not depend on consumption of the marketed outputs.

Principle #3: Charge Different Prices for Different Products if Costs Differ Across Products

Even if there are no fixed costs and no nonmarketed outputs, the break-even principle does not provide sufficient guidance for price setting. Under the break-even principle, the main goal is to ensure that prices are on average correct in the sense that the sum of revenues earned from all products equals the sum of costs incurred from all products. Thus, for example, if one product exhibited a low cost of production and another exhibited a high cost of production, it would be acceptable to charge the same (medium) price for both products so that the firm broke even over-all. This in not correct. The price of an ***individual*** product is a signal of the cost of that ***individual*** product. Thus, the price of each product must be set equal to the cost of producing that product.

CHAPTER 3

Depot-Level Reparables

This paper is specifically concerned with the Air Force's system for supplying, maintaining, and repairing depot-level reparables (DLRs).[1] This chapter describes the main features of this system and how transfer pricing is currently used.

BACKGROUND

A military aircraft is designed as a series of replaceable components in order to maximize its availability for operation. When a malfunction occurs, the component that malfunctioned is removed at the flight line and immediately replaced by a functioning component from a locally available inventory of functioning spares. Then, the issue of what to do with the broken component can be turned to. Some repairs are accomplished on base by the military units themselves. However, more complex repairs requiring specialized equipment are often performed in central repair depots owned and operated by the Air Force. Regardless of where repair typically occurs, all of these components are generally referred to as depot-level reparables.

Individual military units can be viewed as the "user divisions" in this situation. The "service center" is the entire supply system for DLRs, which consists of two parts, a central logistics agency and a number of Air Force-owned and operated repair depots. The supply system provides two services to military units. First, it supplies access to inventories or inventory maintenance.[2] Central logistics is the owner and manager of all inventories of functioning DLRs; one of its jobs is to maintain an adequate supply of inventories available for each military unit. Second, in the event that the military unit decides not to repair a broken DLR itself, the supply system arranges a repair/replacement. That is, it acts

[1] Each of the three Services operate relatively separate DLR systems. The systems are similar and most of the comments made in this paper apply equally well to the other two Services' systems. However, there are a few differences. Therefore, to avoid an endless series of qualifications and discussions of special cases, this paper will restrict itself to specifically discussing the Air Force system.

[2] In this paper, the terms "providing access to inventories" and "maintaining inventories" will be used as synonyms to describe this first function.

as an intermediary among the military unit and repair depots and manufacturers of new parts. The military unit simply turns the broken component over to central logistics which arranges to repair the component at a depot or to replace it with a new part purchased from the commercial manufacturer, if necessary.[3]

An important feature of this system is that (in order to capture various economies of operation) individual military units are not assigned permanent "ownership rights" in particular DLRs. When a military unit turns a DLR over to central logistics for repair/replacement, the military unit draws a new DLR from the local inventory and keeps this. The submitted DLR is not specifically tracked and eventually returned to the military unit that submitted it. Rather, it is simply repaired and placed in the nationally available inventory pool for the DLR type. Similarly, when a military unit decides to undertake a repair itself, it initially withdraws a functioning DLR from the local inventory and installs it on the aircraft. Then, it repairs the broken unit and turns it into the local inventory managed by central logistics.

Prior to 1991, transfer prices were not used in the relationship between military units and the supply system. The supply system was directly funded through appropriations; military units simply requisitioned services from the supply system as necessary.[4] A set of regulations, at least in principle, described how military units should make the location of repair decision for every possible malfunction of every possible DLR.

In 1991, the supply system was turned into a service center operating under the break-even principle. The supply system no longer received direct appropriations from Congress. Rather, appropriations were given to military units who paid these appropriations to the supply system in order to receive services.

Prices were established as follows. Let n denote the number of types of DLRs used by the Air Force. Then the service center was decreed to produce n marketed products, where product i was the repair of DLR type i. An accounting system was established that allocated all of the costs of the supply system to one of these products and the price of product i was set equal to its accounting cost.

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[3] Throughout this paper, the term repair/replacement will be used to denote the supply system's function of repairing the malfunctioning DLR at a depot or replacing it, if necessary, with a new DLR purchased from the manufacturer.

[4] Even prior to 1991, transfer prices were used to organize decision-making within the supply system. Depots have always operated as self-supporting service centers by selling their repair services to central logistics. Since this paper is concerned with the impact of transfer prices on decision-making by military units, there is no need to explicitly discuss this extra complexity.

The actual method for collecting these prices from users was most naturally implemented by separating the two transactions of withdrawing a spare from inventory and returning a spare to inventory. A "standard price" was set for each type of DLR. Let s_i denote the standard price of DLR type i.[5] Then, whenever a military unit withdrew a functioning DLR of type i from local inventory, it was required to pay central logistics s_i dollars. Similarly, whenever a military unit returned a functioning DLR to inventory, central logistics was required to pay the military unit s_i dollars. Finally, if the military unit returned a broken DLR to inventory, central logistics was required to pay the military unit $s_i - p_i$ dollars.

Now consider the result of this system for the two possible decisions of the military unit when it has a broken DLR. If it decides to repair the unit itself, it immediately withdraws a spare from inventory and pays central logistics s_i dollars. Then, after it completes the repair, it returns the repaired item to inventory and receives s_i dollars from central logistics. Thus, its net payment to central logistics is zero. If it decides to have central logistics handle the repair/replacement, it turns in the broken unit and receives $s_i - p_i$ dollars. However, it simultaneously withdraws a new unit and pays s_i dollars. Therefore, its net payment is p_i. Therefore, the result of this system is just as described above. Military units were required to pay a price of p_i when they requested that central logistics handle a repair/replacement, and nothing otherwise.

USER DECISIONS

Of course, the rationale for charging prices to users of internal inputs is to improve decision-making over the use of these inputs by decentralizing resource usage decisions down to the level of these users. Therefore, the natural first two questions to ask are:

1. What usage decisions are made?

2. Would there by any value in decentralizing these decisions?

Each of these questions will be considered in turn.

It is possible to distinguish between two types of decisions made over the use of the services offered by the supply system. The first type of decision is the "location of repair" decision. Given that a malfunction has occurred, and a DLR has been withdrawn from the aircraft and replaced by a functioning DLR, should the military unit repair the DLR itself or should it immediately turn it over to central logistics for repair/replacement? The basic trade-off from the perspective of the Air Force as a whole is that repair at central depots can often be cheaper because specialized test and repair equipment can be more fully used. However, extra transportation costs are incurred and the turn-around time is increased. Roughly similar magnitudes of repair work are performed on-base and in

[5] The exact value of this standard price is of no particular consequence since it essentially performs the bookkeeping task of temporarily keeping track of withdrawals that have not yet been matched by a deposit.

depots[6]; there has been considerable attention in the Air Force devoted to the issue of whether a different division of responsibilities would be more desirable [Camm and Shulman (1994)]. Therefore, it appears that this is a significant decision.

The second type of decision will be called "decisions affecting the number of malfunctions." Just as the term states, these are decisions that affect the number of malfunctions military units produce. Two examples of such decisions are force structure decisions and training-intensity decisions.

Now, the question of the desirability of decentralizing these decisions will be turned to. Of course, given the enormity of the Air Force and the tasks it is involved in, central decision-makers cannot possibly hope to make all decisions themselves. Thus, by necessity, significant decision-making authority must be delegated to lower levels of the organization.

The primary goal of introducing transfer pricing between military units and the supply system was probably to decentralize the location of repair decisions. Prior to the introduction of transfer pricing, central authorities essentially tried to control this decision themselves through regulations. Complex sets of regulations existed that, in theory, described how the location of repair decision should be made for every possible malfunction of every DLR. In reality, even major policy decisions regarding the nature of these regulations were largely delegated to the level of operational commands. Presumably, if the supply system required more resources, there would be fewer resources left for operational commands. However, there was no direct mechanism in place to make commands aware of and responsible for costs of the supply system. Thus, it was not clear, even at the level of establishing overall policy, that the location of repair decisions being made fully internalized the cost of the supply system. The situation was even more extreme at the base level, where individual military units made a variety of day-to-day or routine decisions regarding location of repair. Individual military units were completely unaware of the costs to the supply system of accomplishing various repairs. Thus, it was impossible for them to attempt to compare the cost of on-base repair with off-base repair and choose the least cost alternative. Instead, they would simply try to follow regulations, and make decisions in gray areas using other criteria. Thus, commanders of individual military units had neither the knowledge nor incentive to attempt to make location of repair decisions that minimized costs to the Air Force as a whole.

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[6] The Air Force does not keep cost accounts in such a way that the cost of on-base repair and maintenance of DLRs can be separately identified. Conversations with experts at LMI suggest that roughly similar magnitudes of work are accomplished in each location. However, this estimate is very approximate and should be interpreted as meaning that the volume of work accomplished at the depot level is not an order of magnitude larger than the volume of work accomplished at the base level. Dollar estimates of the cost of repair work accomplished at the depot level will be presented further on in this section.

The idea underlying the introduction of transfer prices, was that, so long as prices of repairs were equal to the cost to the supply system of providing these repairs, then commands and the military units below them would have both the information and incentive to make cost-minimizing decisions. Decision-makers could compare prices of the supply system with the cost of doing repairs on-base and, by selecting the alternative that cost them the least, they would also select the alternative that cost the Air Force the least.

Although the potential also exists for transfer prices to help decentralize the second type of decision (decisions affecting the number of malfunctions), less attention has been paid to this. This is possibly because operational decisions and force structure decisions are viewed as more important; thus, decision-making authority is retained by central authorities to a larger extent. Certainly, few of these decisions are made by commanders of individual military units. However, operational commands certainly influence various training methods and force structure decisions, so it may be that transfer prices may also create better incentives for these decisions.

Since it appears that the main intent of transfer pricing was to decentralize the location of repair decision, and since the major focus of debate has been on the effects of transfer pricing on this decision, we focus on the location of repair decision in this paper. However, we also mention effects on decisions over the number of malfunctions when these effects seem important.

The new transfer pricing system was not fully implemented until 1993. Furthermore, we suspect that insufficient time has elapsed to observe the long-run response of military units to this system. Nonetheless, there are some indications that decision-making behavior may be responding quite dramatically to the new system, and the nature of the response appears troubling to at least some observers. In particular, it appears that military units and the commands above them are responding to this price system by attempting to shift large amounts of repair to the base level that were formerly done at the depot level. This is troubling, because according to analysis it has done itself, the Air Force believes that many of these repairs should have been performed at the depot level in order to minimize costs to the Air Force as a whole. See Camm and Schulman (1994) and Glass (1994) for a discussion of this.

Costs of the Depot-Level Reparables System

Table 3-1 presents a breakdown of the costs of the Air Force DLR supply system for FY94. Approximately half (49 percent) of all the supply system costs are incurred at the repair depot level. Another 23 percent of costs are incurred to purchase new spares to replace parts that are beyond repair. The remaining 28 percent of costs are incurred at the central logistics level.

Table 3-2 presents data available on the breakdown of costs within central logistics. A relatively small fraction (6 percent) of central logistics costs is devoted to transporting goods. A similarly small fraction (8 percent) is devoted to

building up inventory levels.[7] The remaining 86 percent includes costs of storing inventories as well as costs of managing and supervising the entire supply system.

Table 3-1.
Air Force DLR Supply System Costs for FY94

Item	Amount ($ millions)	Percentage of total
Depot repair	1,659	49
Replacement	766	23
Central logistics	966	28
Total	3,391	100

Source: Wallace (1994).

Table 3-2.
Central Logistics Costs for FY94

Item	Amount ($ millions)	Percentage of total
Transportation	62	6
Inventory buildup	82	8
Other	822	86
Total	966	100

Source: Wallace (1994).

Table 3-3 presents another way of viewing supply system costs. As discussed above, the supply system performs two different tasks for military units, inventory maintenance and repair/replacement. The cost elements in Tables 3-1 and 3-2 of depot repair, replacement, and transportation can all be thought of as costs directly incurred to support the repair/replacement function. These are probably the only significant such cost elements.[8] From Tables 3-1 and 3-2, the sum of these three cost elements is $2,487 million, or 73 percent of total supply system costs. The remaining 27 percent of costs consists of some costs that can be directly associated with only providing access to inventories (such as the cost of inventory build-up) and some costs that support both activities. Although no

[7] The initial complement of spares is provided free to central logistics as part of the initial procurement. However, it often turns out that, due to unexpectedly high failure rates in some components, the inventories of some components must be increased.

[8] It may be that some central logistics personnel could be unambiguously classified as supporting only repair/replacement and access to inventories, but this is likely to be very small.

complete breakdown is available, we suspect that the majority of these costs are administrative costs that support both activities.

Table 3-3.
Air Force DLR Supply System Costs for FY94

Item	Amount ($ millions)	Percentage of total
Direct costs of repair/replacement	2,487	73
Other	904	27
Total	3,391	100

Source: Wallace (1994).

CHAPTER 4

Costs of Nonmarketed Outputs and Fixed Costs

ACCESS TO INVENTORIES

The supply system provides two conceptually separate outputs to military units, inventory maintenance, and repair/replacement. Only repair/replacement is treated as a marketed output. Thus, under the break-even principle, all of the costs of inventory maintenance are allocated to repair/replacement. This creates a set of incentives for military units that is clearly incorrect. Regardless of where repair occurs, a military unit always relies on the supply system for access to an inventory of functioning spares to replace the malfunctioning component while it is repaired. Under the current system, costs of the entire supply system are allocated to repair. Thus, a military unit is essentially told that if it decides to perform a repair on base, it can have access to inventories for free. However, if it decides to ask the supply system for repair, it must pay for both repair and the entire cost of maintaining access to inventories. The result is that military units will quite rationally choose to do repairs on-base even when the repairs could be more cheaply accomplished at the depot.

From Table 3-3, the cost element "central logistics costs excluding transportation" (i.e., "Other") equals $904 million or 27 percent of total costs. A clear improvement over the current system would be to allocate none of this cost element to repair/replacement. Some of the costs within this element are variable costs of inventory maintenance. The rest of them are largely administrative infrastructure costs that support both functions and that are probably almost completely fixed with respect to variations in the supply of repair/replacement.

Recommendation #1: Central logistics costs other than transportation costs should not be allocated to repair/replacement for purposes of creating prices for repair/replacement.

Table 3-3 shows that this would cause repair/replacement prices to fall by 27 percent. This is a significant price drop.

Of course, it is likely that a small fraction of the excluded costs are actually variable with respect to repair/replacement. If significant, such cost elements could be separately identified at relatively low cost, it would be worth treating them separately. However, inability to achieve 100 percent accuracy is no excuse for inaction. Under current practice, the Air Force is essentially "guessing" that 100 percent of these costs are variable with respect to repair/replacement. The

guess that 0 percent of these costs are variable is quite clearly more accurate by an order of magnitude.

CHARGING FOR ACCESS TO INVENTORIES

Having decided not to allocate $904 million of costs to repair/replacement, the next obvious question concerns who should pay for this cost. The obvious first alternative to consider is to recover it by charging for access to inventories. It would be very straightforward to alter current pricing practices to implement such a plan. The price of a repair/replacement for DLR type i, denoted by p_i, could be calculated just as it is now, only the $904 million in central logistics costs would not be included. Then, a new set of n prices denoted by q_i for $i \in \{1,\ldots,n\}$ would be calculated, where q_i denotes the price of access to inventories for DLR type i. Just as now, when it withdraws a functioning spare from central logistics, a military unit would pay the standard price, s_i. However, when it returns a functioning DLR, it would only receive $s_i - q_i$ from central logistics. When it returns a broken DLR, it would receive $s_i - q_i - p_i$ dollars. Thus, the net price paid to central logistics would be q_i when the military unit did the repair on-base and $q_i + p_i$ when the military unit asks for a repair/replacement.

If it was thought desirable, one could fully allocate the $904 million of central logistics costs to the n products "access to inventories for DLR type i" and thus fully recover the $904 million through this means. Of course, the logic of marginal cost pricing applies equally well to determining q_i as to p_i. The economic function of q_i is to correctly communicate information about the cost of providing access to inventories, because this cost is relevant to determining decisions that affect the number of malfunctions that occur.[1] Therefore, q_i should be set equal to the marginal cost of the supply system of providing access to inventories. This is the marginal cost to the supply system of dealing with an additional malfunction that is repaired on-base.

It is clear that this cost is not exactly equal to zero. Asking for one more access to inventories creates some variable costs of processing the transaction, and also, in theory, means that the optimal level of inventory holdings should be larger. However, we suspect that many, and perhaps nearly all, of central logistics costs are fixed with respect to providing additional access to inventories. This issue obviously needs to be empirically investigated. However, without further empirical study, our tentative recommendation is that q_i ought to be set equal to zero (i.e., access to inventories should remain a nonmarketed good). This is because its marginal cost is probably close to zero, and considerable transactions costs would be avoided by not introducing another set of marketed goods.

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[1] Notice that, while p_i affects both types of user decisions (location of repair and number of malfunctions), q_i only affects decisions about the number of malfunctions. The location of repair decision is made after a malfunction has occurred. Thus q_i will be paid for access to inventories regardless of where repair occurs.

Recommendation #2: Do not establish a price for access to inventories unless further investigation suggests that there are significant identifiable cost elements within this group that vary directly with providing access to inventories. In that case, a set of prices for access to inventories could be established as suggested above to recover these costs.

Prior Year Losses and Gains

Under the break-even principle, prices for a given fiscal year are set in advance so that estimated revenue equals estimated cost. However, unanticipated fluctuations in demand or input prices may cause actual ex-post revenue to differ from actual ex-post cost. The procedure currently followed is to recover last year's loss or disgorge last year's profit by treating last year's loss (profit) as a fixed cost (which may be negative) and allocating it to all this year's products. Thus, from the perspective of this paper, this practice simply creates another fixed cost and this cost should not be included in prices for the same reasons as any other fixed cost should not be.

Recommendation #3: Adjustments to current prices to account for prior year losses and gains should be treated as fixed costs and not allocated to products for the purposes of determining prices.

Thus far, the supply system for DLRs has generally earned a fairly substantial loss. For example, in FY94, the prior year loss that was recovered was $191 million [Wallace (1994)], which is approximately 10 percent of supply system costs for FY94. Thus, in FY94, the average price of a repair was 10 percent too high due to the inclusions of this fixed cost in prices. This is a significant distortion.

Other Nonmarketed Outputs and Fixed Costs

The other major possible nonmarketed output of the supply system is the output of wartime capability and capacity. The concept is quite simple. It is unlikely that the supply system is designed to provide peacetime repairs at the lowest possible cost. The system is much larger and more elaborate than it needs to be in order to be able to meet peacetime needs. The current system does not explicitly recognize an output called wartime capacity. Thus, all of these costs are allocated to peacetime repairs.

Also, there may well be fixed costs at both the central logistics and depot level due to economies of scale and scope.

With regard to central logistics costs, the previous parts of this section have already recommended that all of these be treated as fixed costs. The two points above provide extra support for this recommendation.

With regard to depot-level costs, it is less clear how to proceed. It is unlikely that it would be possible to directly calculate the costs of wartime capacity or fixed costs due to economies of scale and scope at the depot level. The Air Force should continue allocating all depot-level costs to products for the time being. The desirability of the recommended changes is much more clear and obvious than the desirability of attempting to identify cost elements at the depot level that should not be allocated. After the system has had time to equilibrate in response to these changes, the Air Force could perhaps return to this question.

Recommendation #4: For the time being, costs at the maintenance depots should continue to be fully allocated to products for the purposes of creating prices.

Paying For Fixed Costs

According to the recommendations above, all central logistics costs except for transportation costs, should be treated as fixed costs. This is also the case for cost elements associated with adjustments for prior year losses or gains. It is also possible that the Air Force might eventually choose to treat some elements of depot repair cost as fixed. If these costs are not recovered through prices, how should they be recovered?

One option is to abandon the practice of funding central logistics through payments from users. The Air Force could return to the old practice of funding central logistics through direct appropriations. Under this option, central logistics would be removed from DBOF. Under the second option, users would continue to pay for the services of central logistics and thus it would remain a part of DBOF. They would do this by being charged fixed annual fees by central logistics that did not depend on their use of repair/replacement services. The simplest alternative would be to have the single central authority in the Air Force that is responsible for all operations to pay a single annual fee. It might be possible to charge some fees at lower levels of the organization. For example, some costs might be clearly specific to a particular type of DLR and a single command may be the sole or major user of that particular type of DLR. Then, the command could be directly charged for these fixed costs.

Both of these alternatives would have the same impact on decisions of military units and thus, from the perspective of issues analyzed in this paper, are identical. However, along some other dimensions, these alternatives might have quite different impacts. Funding central logistics through DBOF has at least two effects. First, money that an agency receives as revenues from sales is in a sense "laundered." Many of the normal restrictions involving use of appropriated funds no longer apply and the spending agency has much more freedom to use the funds for different purposes. Second, it is also alleged that DoD controllers gain some extra leverage over funds in DBOF due to the responsibilities they are assigned for "cash management." Whether these effects are good or bad depends on who you talk to. Individuals within central logistics often speak

highly of the first effect.[2] Individuals within DoD's Comptroller's Office are undoubtedly enthusiastic about the second effect.

This paper does not attempt to analyze the issue of whether it is desirable to retain central logistics within DBOF. The main point of this paper, with respect to this issue is that it is completely separable from the issue of whether central logistics should be funded through prices charged for repairs. It is possible to fund central logistics through other types of user charges and retain central logistics within DBOF. Since this involves the smallest change from current practice, we recommend this change. However, it would also be possible to remove central logistics from DBOF if this was thought to be of independent value.

> ***Recommendation #5: Central logistics and adjustments for prior year losses and gains should be funded by users through direct annual fees charged to higher levels of the organization within the Air Force. These fees should not depend on consumption of repair/replacement services.***

[2] One such official told the author that this was the main advantage of DBOF. As an example, he cited cases where his agency chose to spend money on R&D to redesign a part to save future repair expenses. Such a fund-shifting activity would be difficult or impossible under the normal appropriations process.

CHAPTER 5

Further Recommendations

DISTINGUISHING BETWEEN REPAIR AND REPLACEMENT

Under the current system, for a given type of DLR, a military unit is charged the same price for a repair as a replacement.[1] The actual cost of a repair is, on average, much lower than the cost of a new component. For example, Camm and Schulman (1994, Table 1) report that for the seven major DLRs on the F-16 aircraft, the average repair cost was only 4 percent of the average replacement cost (i.e., buying a new component cost twenty five times as much as the typical repair). This is not surprising in light of everyday experience with automobiles. A new car may cost $20,000. Four percent of this is $800.

Under the current system, the supply system charges a single price for repair/replacement so that it breaks even on average. According to Table 3-1, replacement costs are 23 percent of supply system costs. Thus, repair prices would be reduced by approximately 23 percent if replacement costs were not allocated to them. This is a significant price drop.

How should replacement costs be recovered? Straightforward application of marginal cost pricing (Principle #3) suggests that two separate prices should be charged. Let c_i^d and c_i^n denote, respectively, the marginal cost of a depot repair and new replacement for DLR type i. Then, a military unit should be charged c_i^d if the unit it turns in can be repaired, and c_i^n if the unit needs to be replaced.

The major benefit to this pricing change would be caused by the drop in prices by approximately 23 percent. This would have a significant impact on the location of repair decision. The rise in price for replacements would have no effect on the location of repair decision since the base has no choice but to return a unit that is beyond repair. Therefore, it is not as important that price of replacement be raised to the marginal cost of replacement. The only user decisions that are significantly affected by the marginal cost of replacement are force structure decisions. That is, doubling the number of aircraft will probably double replacement costs; prices should be set so users are aware of this. Charging a military unit the marginal cost of a replacement when a replacement is necessary is certainly one way to accomplish this. However, it has the disadvantage of introducing a considerable amount of uncertainty into a military unit's budget forecasts. A simple alternative pricing method that preserves incentives for force structure planning, but does not induce uncertainty at the military unit level, would be to

[1] For the purposes of this section, assume that all repairs for a particular type of DLR cost the same. The next section will discuss how prices need to be altered to reflect the fact the cost of repair may vary significantly from item to item within the same type of DLR.

charge military units a fixed annual fee per employed DLR to cover expected replacement costs. Thus, a military unit employing twice as many aircraft would pay twice as high an annual replacement fee.[2]

Recommendation #6: A military unit should be charged the marginal cost of a repair whether the unit it submits is repaired or condemned. For each type of DLR, the excess of condemnation costs over revenues collected for condemned units should be aggregated in a single pool and charged as an annual fee to users of that DLR. One method would be to charge in proportion to the number of such DLRs they deploy.

Distinguishing Between Degrees of Difficulty of Repair

The supply system has set a single repair price for each DLR type that does not vary according to the nature of the malfunction of the DLR. Thus, the supply system charges the same price for easy repairs as for difficult repairs. The completely unsurprising result of this has been that military units have begun to perform repairs of below average difficulty on base, even if they could be performed more cheaply at the depot. The reason is that the supply system does not offer to do the easy repair for a price equal to the actual cost of performing the easy repair. It sets a much higher price equal to its cost of performing a more difficult repair.

We suspect that part of what we have been observing over the past two or three years is a series of initial iterations toward a new long-run equilibrium that may be much worse than what has been seen so far. In its first year of operation, the supply system set an average price for repair under the assumption that it would continue to do the same types of repairs as in past years. The unpleasant surprise it received was that many of the easy repairs migrated over to the bases, resulting in a higher average cost of repair than anticipated. Thus, in year two, the supply system set new higher prices to reflect last year's unpleasant surprise. Of course, the result of higher prices in year two was a new, unpleasant surprise. Even more easy repairs migrated over to the bases, which caused the average cost of a depot repair to become even higher. This will cause a new price adjustment, which will induce a new migration, and so on. Where this process will equilibrate is not yet clear.

Camm and Schulman (1994) discuss an interesting example of distorted decision-making due to this practice. When a component on an aircraft malfunctions and is removed from the aircraft, typically a two-step procedure is followed. First, using various test equipment, technicians attempt to "duplicate" the malfunction. If they cannot duplicate the malfunction (i.e., the component now appears to work properly), then it is simply returned to the inventory of

[2] Another alternative would be to directly charge each command for actual condemnations incurred by military units controlled by that command. This would have the advantage of correctly incentivizing training intensity decisions, if these prove to affect the condemnation rate.

functioning components. If the component malfunctions in the test, then technicians go on to try to repair it. Thus, at a very basic level, we can divide repair actions into two categories – "inspect only" and "inspect and repair."

Under the current practice of charging a single price for all DLRs of a given type, the same price is charged for an "inspection only" as for a "repair and inspection." A price is chosen so that the depot makes a profit on an "inspection only" and a loss an "inspection and repair," but breaks even over-all. Faced with these prices, military units have responded by attempting to do all of their inspections on-base and then only sending units for repair when the malfunction can be duplicated. Camm and Schulman (1994) argue that, from the perspective of the Air Force as a whole, it is actually often cheaper for inspections to occur at the depot.

Another distortion that seems to routinely occur is the creation of "extremely broken" components. Under the current system, a user is charged the same price for turning in a component with multiple malfunctions as for turning in a component with a single malfunction. In this case, it makes sense for military units to devote considerable on-base resources to trading parts among broken components, so as to turn two broken components each with one malfunction, into one broken component with two malfunctions and one functioning component. By so doing, the unit halves its payment to the supply system. However, this activity saves no money at the supply system level, and it may result in significant costs at the base level.[3]

In order to avoid these problems, the Air Force should invest in better information systems that would allow it to keep track of the nature of repairs performed on particular components. This information could be used to determine the price that is charged for repair. It would not be necessary to allocate every cost at the depot level to a particular repair of a particular DLR and literally charge the ex-post accounting cost for each repair. Significant improvements could be achieved by dividing the repair of a component into different, broad types of repairs and charging a price for repair that depends on the type of repair actually done.

Recommendation #7: Prices charged for repair should depend on the difficulty of the required repair.

EXCESS SUPPLY OF INVENTORIES

Because of the massive force reductions currently underway, the Air Force is currently in the position that it has excess inventories of some components. In some cases, the Air Force actually owns sufficient inventories to supply all foreseeable demand without ever repairing another part or purchasing another new part. In this case, the component is said to be in "permanent excess supply" or

[3] It may be that the supply system saves some money by having to supply only one "access to inventory" instead of two. If this is true, then this should be reflected by introducing a price of inventory access, q_i, as described in Chapter 4.

"long supply." In other cases, the Air Force will eventually have to begin replacing or repairing broken components. Such components are said to be in "temporary excess supply."

The current practice of the Air Force is to have the supply system charge a price equal to the cost that would be incurred if the unit was repaired immediately [Glass (1994)]. To understand the problem with this practice, consider the simplest case of an item in long supply. Suppose that the cost of a depot repair is $5,000, and the cost of an on-base repair is $4,800. A military unit breaks a component. What should occur? Since the item is in permanent excess supply, the marginal cost to central logistics of providing the user with a functioning component is actually zero. Therefore, the correct decision is for the military unit to turn in its broken component to central logistics, for central logistics to issue a functioning component from inventory, and for the broken component to never be repaired. Suppose that central logistics sets a price equal to $5,000 (as is current practice). The military unit would then, quite rationally, decide to repair the unit on-base for $4,800, since this is less expensive than ordering a repair from the depot. Thus, the distortion that occurs is that military units will potentially repair units on base when the optimal policy is that no repairs should be done anywhere.

As usual, the solution to this problem lies in setting price equal to marginal cost. In the case of a component in long supply, the marginal cost of repair is zero, so the price of repair should be set equal to zero. In the example above, a price of zero induces the military unit to correctly perceive that repairing the unit on base would cost the Air Force as a whole $4,800.

More generally, consider a case where there are t years of excess supply available. Suppose that c is the repair cost of the component. Then, the effect of turning in an extra broken component today is that t years from now, the supply system will have to perform one more repair. That is, t years from now, the supply system will spend c more dollars. Let r be the appropriate interest rate that the government should use for discounted present value calculations.[4] Then the cost to the supply system of receiving one more broken unit today is

$$c/(1+r)^t.$$

This rule is very intuitive. For an item that is not in excess supply, t equals zero, so the price should be c. For an item in permanent excess supply, the price should be zero. As the number of years of excess supply grows from zero to infinity, the price drops from c to zero.

[4]Various theoretical and practical solutions exist for determining such an interest rate.

It would be fairly simple to implement the correct pricing rule in this case. Central logistics should simply estimate the number of years of excess supply that it has on hand and then charge a price equal to the discounted repair cost.[5] Note that such a system would cause the supply system as a whole to earn a profit for items in temporary excess supply. If it was desired, one could eliminate this profit by lowering the charge for fixed costs by the amount of profit expected to be earned.

Recommendation #8: For items in temporary excess supply, the repair price should be discounted by the number of years of excess supply. For items in permanent excess supply, the repair price should be zero. Profits earned on items in temporary excess supply could be refunded by lowering the annual fee charged for fixed costs.

NONFUNGIBLE BUDGET CATEGORIES

Military units do not receive a single budget total that they can allocate as they wish between alternatives. Rather, resources are allocated to them in different categories, and they are not free to move funds across categories. Camm and Shulman (1994) have quite correctly pointed out that the implications of this for the effects of transfer pricing on decision-making need to be considered. In this section, we begin by explaining the basic issue that raises concern. Then we argue that this does not appear to create a significant problem.

A military unit receives a budget allocation for operation and maintenance (O&M) as well as an allocation of military manpower. Resources are not fungible across these categories. That is, there is no way for a commander to return a few military personnel and receive their salaries as part of his O&M budget. It is widely accepted in military circles (although the reasons for this are not well understood) that commanders of military units are almost always in a position where the opportunity cost of military manpower is much less than the opportunity cost of O&M funds. That is, generally speaking, a military commander would be willing to trade military manpower resources for O&M dollars if he were allowed to do so.

From the viewpoint of a military unit, the decision to perform more repairs on-base and to ask for fewer depot-level repairs involves a substitution of military manpower resources for O&M resources. That is, by doing one more repair on base, the military unit uses more of its military manpower to perform the repair, but saves the O&M money that it would have paid to the supply system.

As discussed in Chapter 3, the outcome of introducing transfer prices for DLRs appears to be that more repairs are being done on base and that perhaps "too many" repairs are being done on base relative to what would be cost

[5] Note that changes in price may well affect current demand, which in turn will affect the number of years of excess supply. Therefore, in some cases, the price may have to iterate through a number of adjustments before an equilibrium is reached. However, this should not pose any particular problem.

minimizing for the Air Force as a whole. Of course, one explanation for this inefficiency is the existence of the major pricing errors described in previous sections. However, one troubling aspect of this behavior regards its relationship to the existence of nonfungible budget categories. In a sense, it seems that military units are taking advantage of transfer prices to essentially do what they could not do directly (i.e., to convert military manpower resources into O&M funding).

Consider the following example: Suppose that the commander of a military unit has excess military manpower for which he has no good use. Suppose that he can use $100,000 worth of this manpower to do on-base repairs or spend $10,000 in O&M funds and have the repairs done at the depot. From the commander's perspective, the opportunity cost of the manpower resources is zero. Therefore, he would rationally choose to do the repairs on base and save $10,000 worth of O&M funds that have many good alternate uses. Thus, transfer pricing essentially allows the unit commander to trade $100,000 worth of manpower resources for $10,000 worth of O&M funds.

This behavior certainly raises the question of whether transfer pricing at marginal cost will induce military units to make efficient decisions. Instead of making efficient decisions, they may simply perform as many repairs on base as possible to essentially circumvent the restriction that manpower resources cannot be traded for O&M resources.

The main point of this section is to argue that the issue of whether nonfungibility across budget categories induces users to make distorted decisions is actually more subtle than the reasoning above suggests. All of the behavior described above may in fact be perfectly consistent with transfer prices working perfectly.

Consider the example described above where the military unit essentially trades $100,000 worth of manpower resources for $10,000 worth of O&M dollars. There are really two separate decisions that the government, as a whole, had to make in this case:

- *Decision #1:* How many military manpower resources and how much O&M funding should the military unit be given?

- *Decision #2:* Given the result of Decision #1, how much repair should be performed on base by military manpower?

The important point to note is that the military unit was making Decision #2 and not Decision #1. In all likelihood, the military unit made the correct choice for Decision #2 from the perspective of the Air Force as a whole. Given that Decision #1 had been made, and that the military unit was given such large levels of manpower resources, the opportunity cost to the Air Force of using these resources for on-base repair was probably zero, just as the military unit perceived it to be. That is, given that the personnel are stationed at the base and paid and housed there, it would cost the Air Force as a whole nothing to have

the personnel perform on-base repairs. Therefore, the military unit actually made Decision #2 correctly.

The real issue being raised is that higher authorities within Congress or the Air Force may have made Decision #1 inefficiently. But this is not the decision that transfer pricing is supposed to support. Given the answer to Decision #1, the goal of transfer pricing is to have the military unit make Decision #2 correctly. Transfer pricing at marginal cost accomplishes this.

Furthermore, it is not necessarily clear that a mistake has been made in Decision #1. For example, it is possible that the military unit is given these manpower resources so that wartime capability is available. Given that military manpower must be in place for wartime capability, the marginal cost of using this manpower to perform peacetime repairs may well be very low. However, even if Decision #1 was made completely incorrectly, the goal of the Air Force at the time Decision #2 is made should be to perform the repairs in a way that the extra cost to the Air Force is as small as possible. Pricing depot repairs at marginal cost accomplishes this.

It is possible to complicate the above example in a few ways to support the conclusion that the observed behavior is the result of the military unit making Decision #2 incorrectly. In particular, suppose that the following two assumptions are true:

- ***Assumption #1.*** The military unit commander can allocate manpower between maintaining wartime capability and accomplishing peacetime repairs, but performing more of one function results in less performance of the other. That is, war-time capability and peacetime repairs are substitutes in production.

- ***Assumption #2.*** For some reason, the commander of the military unit does not value wartime capability as highly as do central authorities within the Air Force.

If these two assumptions are true, then the following theory is consistent with observed behavior. Central authorities within DoD value wartime readiness more highly than do unit commanders. Central authorities gave military units large amounts of military manpower to enable the units to maintain the desired level of wartime readiness. Commanders of military units were not particularly interested in maintaining wartime readiness, but there was no effective alternate use for these resources so they used the resources to maintain readiness. When transfer prices were introduced, unit commanders were essentially offered a way to use military manpower resources to accomplish tasks that they were more interested in. They did this, which resulted in a less effective allocation of resources from the perspective of central authorities.

Although this theory is logically consistent, neither of the two assumptions it is based on are particularly plausible. With respect to Assumption #1, there is no reason to believe that wartime readiness and peacetime repairs are substitutes

in production. In fact, they may be complements (i.e., performing peacetime repairs on-base maintains the unit's competency and makes it more ready to support wartime activities). With respect to Assumption #2, it is not clear why unit commanders should undervalue wartime readiness.

Therefore, it is theoretically possible that transfer pricing at marginal cost could produce distorted user decisions when users have access to nonfungible pools of funds. However, the mere existence of nonfungible pools of funds does not mean that transfer pricing at marginal cost distorts decisions. Although one can concoct scenarios where this occurs, these scenarios do not appear to be that plausible. Therefore, although this issue clearly warrants more analysis, in all likelihood, it will not pose a significant problem.

CHAPTER 6

Conclusion

POLICY RECOMMENDATIONS

This paper essentially makes three major policy recommendations for changing the way that the Air Force calculates transfer prices for the services that the DLR supply system provides to military units. The first recommendation is that central logistics costs[1] be funded by direct annual charges to central authorities[2] within the Air Force, which do not depend on the number of repair/replacements used by individual military units.

The second recommendation is that the cost of purchasing new replacement parts be funded by direct annual charges to military units (or the commands above them) on the basis of the number of deployed DLRs. Both of these cost elements are funded through prices the supply system charges for repairs, even though these costs are largely fixed with respect to repair. The result is that repair prices are approximately twice as high as the actual cost to the supply system of providing these repairs. Military units are essentially being told that, if they choose to repair a DLR on base, they need only pay the repair cost; but, if they choose to repair the DLR at the depot, they must pay a price equal to approximately double the repair cost in order to help fund other activities. The result of this is that military units choose to do repairs on base, even when the true cost to the Air Force as a whole would be lower if repairs were done at the depot.

The third major recommendation is that the price charged for repair of a particular type of DLR needs to be made dependent on the difficulty of repair required for that particular DLR. Under the current system, where a single price is charged for *any* repair of a given type of DLR, military units choose to perform repairs of below average difficulty on-base, even if they could be performed more cheaply at the depot.

In none of these cases are military units making "unethical" or "inappropriate" decisions. Military units are making decisions that minimize their costs of obtaining repairs given the prices that the Air Force sets for depot-level repairs. The problem is not with military units decision-making behavior, but rather with the way that prices are set. Transfer prices should be set so that the prices of depot level repairs are equal to the cost to the supply system of providing these repairs. Then, when they attempt to minimize their own cost of obtaining repairs, military units would automatically make decisions that were cost-efficient from the perspective of the Air Force as a whole.

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[1] Excluding some minor elements such as transportation, which clearly vary with the number of repair/replacements performed.

[2] And in some cases costs can be funded by directly changing operational commands.

The idea that internal transfer prices can be used to decentralize and thus improve location of repair decisions is a good one. Furthermore, the observation that military units apparently do respond to prices supports its plausibility. The major problem is that prices have not been set equal to the cost to the supply system of providing depot repairs. However, this problem appears to be fairly easy to fix. Therefore, it seems that a revised set of transfer pricing practices might well be a useful device to help the Air Force improve it decision-making. However, the errors being made by current pricing practices are enormous and are likely to result in major errors in decision-making. Thus, revising its transfer pricing rules should be a top priority for the Air Force.

Implications for Defense Business Operations Fund

Each year, $81 billion of supply and logistics services are bought and sold in internal DoD markets. Prices in these markets are set largely under the break-even principle. That is, the focus is largely on the funding issue of making sure that internal business units break even. In order for prices to provide decision-makers with the correct information on which to base decisions, prices must be set equal to marginal cost. Use of the break-even principle results in three types of errors: First, the costs of producing nonmarketed goods are included in the prices of marketed goods. Second, costs that are completely fixed are included in the prices of marketed goods. Third, situations where prices are "on average" correct, but are extremely incorrect for individual products, are allowed.

This paper has shown how these pricing errors could create distortions in decision-making within the particular supply function of repair and maintenance of DLRs in the Air Force. It has also shown that, in many cases, simple and feasible pricing rules exist that would significantly improve decision-making. Although we have not studied other areas of the supply system in as great detail, we believe that similar types of errors occur throughout the DBOF and that similar types of solutions would be possible.

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13. ABSTRACT ***(Maximum 200 words)***

Each year, approximately $81 billion of supply and logistics services are bought and sold in internal Department of Defense (DoD) markets. Supply and logistics agencies within DoD are generally run as self-supporting business units. They sell their goods and services to DoD customers and charge prices that allow them to break even. Setting prices according to the break-even principle creates a "neat and tidy" funding system for supply and logistics organizations. However, it is inconsistent with the primary role that transfer prices are supposed to play in an organization. This is encouraging users of internally supplied inputs to make efficient decisions by making them aware of and responsible for the cost of producing these inputs. In order to accomplish this function, transfer prices must be set equal to marginal cost pricing. Incorrect pricing results in significant inefficiencies in resource allocation decisions. This paper considers the case of repair and maintenance of aircraft components by the Air Force. It provides a specific and detailed analysis of pricing errors in this system, the distortions in decision-making that these errors induce, and specific detailed recommendations for fixing these errors. More generally, it provides an illustration of the types of pricing errors occurring throughout DoD's internal markets for supply and logistics services, and how these could be corrected.

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