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GAIN-SHARING, SUCCESS-SHARING AND COST-BASED PRICING

"In principle. . . a system ought to encourage individuals to do what is right by rewarding them for carrying out. . . desirable policies"
(Weitzman [1976] p.251)

INTRODUCTION

The objective of this paper is to model a new incentive structure for government activities that rewards cost-savings and efficiencies. The model combines "cost-based pricing" (see Pavia [1995]) with the popular business practice of "gain-sharing" (see Welbourne & Mejia [1995]), and a new incentive program we call "success-sharing".

The first section of the paper reviews these three concepts. The next section identifies incentive problems that result from traditional public budgeting practices and offers cost-based "transfer pricing" as an alternative. The third section explores ongoing efforts to implement a transfer pricing system in the Department of Defense (DoD). The paper concludes by offering a new budgeting approach that integrates cost-based transfer pricing with gain-sharing and success-sharing.

Under "fully-distributed" cost-based pricing, firms allocate all costs to their various outputs and then use those costs to set prices. (Pavia [1995] p.1060) In a study of over 500 Fortune 1000 firms, 83 percent

reported using fully-distributed costs to establish prices. (Govindarajan & Anthony [1983]) Government mandates also require many regulated firms, such as public utilities, to use cost-based pricing. (see Vogel-sang & Finsinger [1979], Laffont & Tirole [1986], and Sappington & Sibley [1988])

Another important application of cost-based pricing is in the construction of "transfer prices." (e.g. see Benke & Edwards [1980] or Magee [1986]) Many large, complex, vertically-integrated organizations include separate activities that conduct internal exchanges of goods and services. The challenge faced by these organizations is to govern the relationships among internal activities to promote the goals of the organization as a whole. Many private firms solve this problem through the use of internal transfer prices.

Two important lessons come out of the transfer pricing literature. (e.g. see Kovac & Troy [1989], Eccles [1985], Bruns & Kaplan [1987], and Rogerson [1995]) First, to promote the goals of the organization, transfer prices must correctly reflect costs. Second, internal activities must somehow be rewarded for using transfer price signals to pursue organizational goals. These two lessons hint at a model that combines a cost-based transfer pricing system with a program of organizational incentives.

This paper applies lessons from the transfer pricing literature to a unique subset of government activities—those that "earn" their budgets. Internal DoD support activities financed through the Defense Business Operations Fund (DBOF) offer an illustration. Charging their "customers" (operating forces) regulated cost-based transfer¹ prices, DBOF activities "... sell goods or services to customers with the intent of recovering the total cost of providing those goods and services." (DBOF Handbook [1995] p. 2-1)

Unfortunately, it is well documented that, by itself, "... cost-based pricing may introduce economic inefficiencies such as the failure. . . to control costs of production and a lack of incentives. . . to invest in cost-reducing innovations." (Pavia [1995] p.1061)² This observation is troublesome in the case of DBOF. Designed to "foster a business-like customer/provider approach" the aim of DBOF was to "improve the delivery of support services to the Department's operating forces while reducing the cost of operations." (DBOF Handbook [1995] p.1-1)

Along with DBOF, four approaches have been discussed to help reduce the cost of support in DoD: i.) "outsourcing" and

Gain-Sharing, Success-Sharing and Cost-Based Transfer Pricing: A New Budgeting Approach For The Department of Defense (DoD)*

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APPLICATION AREA:
Resource Analysis,
Social Science Methods,
Logistics

OR METHODOLOGY:
Dynamic Programming,
Cost Analysis

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(*)The Defense Business Operating Fund (DBOF) that I refer to in this paper has recently been replaced by what is called the Defense Working Capital Funds. The name has been changed to protect the innocent. For the purposes of my paper, all of the operating concepts of revolving funds are still in effect. The break-up of DBOF into five separate working capital funds re-emphasizes the management oversight responsibility each of the Services has for their activities. The Office of the Under Secretary of Defense Comptroller (OUSDC) still develops policy and has oversight responsibilities for review of the Services Working Capital Fund budgets. The day-to-day management of the Defense Working Capital Funds facilities remains firmly in the hands of the Services.

"privatization",³ ii.) competition, iii.) deregulation, and iv.) organizational incentives (see the SECDEF's Annual Report [1996], and Directions for Defense (DD) [1995]). The first two approaches are outward looking. They focus on the opportunity for current DoD support to be provided by private firms. The last two approaches are inward looking. They focus on improving conditions under which work is currently done within DoD.⁴

This paper is inward looking. It focuses on internal DoD budgeting and management issues, and the role of organizational incentives. The dual objective of the paper is: first, to offer a framework to help upper-level management evaluate organizational incentives in cost-based pricing systems; and second, to persuade the Operations Research Community to join in this effort to model critical budgeting issues.

Citing the need to "reduce the cost of support to help fund higher priority needs," the Congressionally mandated *Report of the Commission on Roles and Missions of the Armed Forces* (DD [1995]) recommends that the DoD "reduce the cost of . . . support . . . through increased outsourcing and better management." (p.ES-3) The Department is encouraged to identify its "core competencies" or "inherently governmental functions" and outsource or privatize other responsibilities. (p.ES-6) The Report concludes that remaining functions "can benefit . . . by pursuing business practices used in the private sector" (DDp.3-1), and urges the adoption of "[b]etter organizational incentives . . ." (DD[1995] p.4-16).

The Secretary of Defense generally concurs,⁵ emphasizing that (together with the Military Departments) the DoD Comptroller and various Under Secretaries have been ". . . examining new approaches to **create incentives for achieving greater savings and efficiencies. . .**" (SECDEF WJ Perry, DoD News Release No. 470-95, 8/25/95 p.10) This paper combines a model of cost-based pricing with two incentive programs designed to reward cost-savings: gain-sharing and success-sharing.

The goal of gain-sharing is to encourage activities to make an effort to reduce current costs in return for some of the immediate gains from the cost savings. In a cost-based pricing system, cost-savings occur whenever an activity succeeds in driving its actual total costs below its "earned" budget. Under gain-sharing a portion of the cost-savings is rebated to the activity as a reward (in the form of employee

bonuses, extra vacation time, etc.). However, a recent survey article by Welbourne & Mejia [1995] expresses concern that, while numerous case studies suggest gain-sharing can help bring costs down over time,⁶ "[t]he bulk of the extensive gainsharing literature is atheoretical and exploratory in nature." (p.584)

The dynamic, discrete-time optimization model introduced in this paper helps to address this concern. Moreover, this simple deterministic model leads to an important discovery. Gain-sharing alone may not be enough. The dynamics of the model suggest that while gain-sharing is necessary to encourage cost-savings, it may not be sufficient. Under certain conditions, what we call "success-sharing" is required to complement gain-sharing in order for an activity to have a sufficient incentive to invest in cost-reducing innovations.

Success-sharing offers an additional opportunity to reward activities. Suppose a "permanent" stream of cost-savings is obtained from a cost-reducing innovation. Success-sharing takes place when the success of the cost savings generated over time is shared with the activity responsible for those savings. However, it is more common for the success of cost savings not to be shared with the activity responsible for the savings. Instead, future cost savings are typically passed along to customers in the form of reduced prices in future periods.

For example, the stated policy for setting transfer prices charged by DBOF providers is that: "If costs are reduced, then prices will be reduced the following year to pass along the savings to the customer." (Business Management Directorate [1993]) Thus "[r]educed . . . costs translate to reduced prices. . ." (Isosaari [1996]p.17) However, providers "have to be confident that prices will stay high enough to recoup [investments in cost-reducing innovations]. . . [since] if once investments are made, regulators slash prices, [those providers] may be leery of investing again." ("The Regulatory Experiment," *The Economist*, Jan. 28, 1995 p.64)

In the case of DBOF, investment costs for both capital assets and management improvements are recovered through depreciation expenses (or "capital surcharges") factored into future year rates. In general, under gain-sharing, activities face a difficult trade-off. While cost-reduction efforts increase current-year pay-outs, resulting price cuts tend to squeeze potential gains from future cost savings. Unless future revenues are discounted at an unreason-

ably high rate, gain-sharing alone may not be sufficient to encourage investments in cost-reducing innovations. In this case success-sharing has an important role to play.

Success-sharing refers to the degree to which any "permanent" savings are shared between customers and the activity responsible for the cost savings. By definition, there is no success-sharing if the activity responsible for the cost savings does not share in the permanent stream of savings. In this case, any long-run benefits are enjoyed entirely by customers who pay new lower prices that fully reflect the cost savings.

Multiyear defense contracts offer an illustration. These contracts are often written in such a way that they effectively guarantee defense firms 100% gain-sharing, but no success-sharing. According to Rogerson [1994], the "DoD essentially makes the following bargain with the firm. In return for revealing its ability to lower costs, DoD will let the firm keep the benefits [the difference between the negotiated price and actual costs] for the duration of the multiyear in which costs are lowered." (p.78) These "benefits" correspond to 100% gain-sharing over the period of the contract. However, "on subsequent contracts, DoD will take the benefits itself." (p.78) Thus, "when a defense firm discovers a way to lower its production costs, previously negotiated prices are not changed. Firms are able to keep profits created by such cost reductions until negotiations take this new efficiency into account and lower prices on future contracts." (p.72) Any profits earned through cost reductions can be thought of as pay-outs from a 100% gain-sharing program. However, since future contracts translate the firm's cost reductions directly into lower prices, there is no success-sharing.

Success-sharing only takes place if, in subsequent periods, the regulated (or "negotiated") price is "stabilized" or only partially ratcheted down. In this case, while customers (e.g. the DoD) might still enjoy the benefit of new lower prices, those prices do not fully reflect the cost-savings achieved. Thus, success-sharing offers an extra incentive to suppliers to lower costs, since they are allowed to capture part of the future stream of benefits from their cost-reducing investments.⁷

The next section briefly introduces management implications of traditional public budgeting practices, and offers cost-based transfer pricing as an alternative. Although internal

DoD support activities are used as an illustration, the results of the paper are not unique to Defense. The model applies to any regulated activity subject to unit-cost-based (transfer) pricing. The third section explores ongoing efforts to implement transfer pricing in DoD. The fourth and fifth sections model a new budgeting approach that combines cost-based transfer pricing with gain-sharing and success-sharing. The model's notation, assumptions, and stationary equilibrium are presented and discussed. An interpretation of the results, some policy guidance, and directions for future research appear in the concluding section.

TRADITIONAL BUDGETING VS COST-BASED TRANSFER PRICING

In traditional public budgeting systems, government activities submit budget requests each fiscal year to cover the costs of their operations. For example, internal DoD "providers" (support activities) that operate under direct appropriations first submit a budget to Congress, and then receive appropriated funds to generate support for their "customers" (operating forces).

Unfortunately, the traditional budgeting approach has several drawbacks. First, from the point of view of providers, an old adage concerning the appropriate size of budgets is revealing: "some is good, more is better, and... too much is just right." In principle, budget requests are formulated by providers to cover the expected costs of satisfying their customer's requirements. In practice, there is little incentive for support activities to request smaller budgets—even in periods of "down-sizing." Thus, according to Niskanen [1971], Fox [1988], Rogerson [1994], and others, under traditional budgeting there is a built-in bias to "maximize budgets" rather than to seek cost-savings. A parallel issue is that customers (operating forces)—and not providers—are usually in a better position to determine the level of support they require. Thus, under traditional budgeting a real concern in DoD is that "[m]erely reducing our military—in and of itself—will not address the problem of controlling support costs which, if left unchecked will steal scarce resources from the operating forces." (Maroni [1993]p.2)

Another drawback to traditional budgeting is that, while operating forces are in the best

position to determine their own support requirements, they remain largely insulated from cost concerns. In contrast, support activities that receive direct appropriations are forced to tackle cost issues every time they submit a budget. Thus providers tend to be more aware of the cost implications of different levels (and composition) of support than are the customers that receive that support. In fact, under this system, customers sometimes view support as "free."

Unless budgets are unlimited, resource management decisions at all levels, including the operations level, need to take resource costs into account in order to maximize effectiveness (i.e. readiness, deterrence, or combat capability). However, under traditional budgeting "... operating forces [have] neither the responsibility nor the flexibility to make trade-off decisions in determining the optimal amount of support required to sustain readiness." (Maroni[1993]p.3)

Finally, traditional budgeting tends to punish cost savings, manufacture inefficiencies, and often contributes to an explosion of rules and regulations. A noted authority on public budgeting observes that "if departments save money, they run the risk the government will recapture the savings... [and thus] efficient departments may be penalized while inefficient ones are rewarded." (Schick [1988] p.531) Worse yet, cost savings achieved one year make it harder to secure requested budgets in subsequent years: "A bureaucrat who failed to spend [or obligate] his entire budget would be in danger of having his budget cut the next year." (Stiglitz [1986]p.173) Thus traditional budgeting tends to manufacture inefficiencies by leading to familiar "use-it-or-lose-it" year-end spending sprees.⁸

The typical bureaucratic response to combat year-end spending sprees is to impose a detailed set of guidelines that constrains activities' spending, and the timing of that spending, through the fiscal year. This leads to new, constraining regulations, and to costly monitoring and auditing of activities.⁹ One particularly insidious consequence is that government managers increasingly view their role as insuring strict compliance with regulations and "protecting" programs, not in cutting costs or increasing efficiencies. Thus adding layers of regulations further handcuffs management without addressing the underlying perverse incentives to avoid cost-savings.¹⁰ Acknowledg-

ing these problems, the principal deputy Comptroller of DoD, Alice Maroni [1993], emphasizes that managers: "... need to move from a mindset focused on how fast can appropriated funds be obligated and spent, to how much can the cost of certain goods and services be reduced." (p.2)

On the basis of these observations, a good alternative to traditional budgeting would: a) satisfy customer demands, b) increase cost visibility, c) reduce the burden of excessive rules and regulations, and d) reward cost-savings and efficiencies. In DoD, this would have the dual impact of lowering support costs while improving the timeliness and quality of support provided to operating forces.

A cost-based transfer pricing system offers one alternative to traditional budgeting. A permanent concern of top management of large firms and organizations is to insure that users of internally supplied intermediate (or "support") products make efficient use of those products in producing final outputs. Another concern is to insure that internal providers supply those products as efficiently as possible. A standard solution adopted by commercial firms is to use internal transfer prices. (Magee [1986])

In a transfer pricing system, "customers" of internally supplied intermediate products purchase those products from internal "providers." The cost-based transfer prices charged for these intermediate products are designed to encourage customers to make efficient decisions by making them aware of the cost of producing those products. Meanwhile, combining cost-based transfer pricing with organizational incentives (gain-sharing and success-sharing), and/or with the threat of competition (from internal sources, or from outsourcing), can help drive internal providers to make more efficient production and investment decisions.¹¹

The general consensus is that for transfer prices to provide the most efficient resource allocation signals, they should be based on marginal costs—the additional costs of producing the last unit of an intermediate product. (e.g. see Rogerson [1995]) In practice, however, transfer pricing systems are often based on unit costs—calculated by dividing the total costs of producing an intermediate product over some period, by the number of units produced that period.

Three accounting characteristics help explain the popularity of unit-cost-based transfer pricing systems: First, traditional accounting

systems were not designed to collect marginal cost data, and in any case, unit cost calculations are less data-intensive. Second, unlike economist's who assume a "U-shaped" (or quadratic) average total cost curve (where unit costs are high at low output levels, fall to a minimum as output expands further), an (often implicit) accounting convention is to assume that unit costs are independent of output. If unit costs are constant over a wide range of production, then this implies marginal costs equal unit costs over that range. Finally, in the case of multi-product firms, overhead (G&A) costs are difficult to assign to specific units of a single product. Instead, overhead is typically spread over the various products according to some rule, and then averaged into the price/cost charged for specific units of a product. (e.g. see Rogerson [1995])

A first simplifying assumption of the model is that transfer prices are set on the basis of unit costs. A second simplifying assumption is that all relevant costs can be directly assigned to individual outputs.¹² The next section reviews the transfer pricing system currently implemented in DoD, and develops some additional assumptions for the new budgeting model that follows.

UNIT-COST-BASED TRANSFER PRICING

The most widespread use of cost-based transfer pricing in a government setting is found in DoD's Defense Business Operations Fund (DBOF). The DBOF was established in October 1991 by the Secretary of Defense.¹³ It consists of all supply and logistics organizations ("providers") within DoD that sell their outputs to other organizations ("customers") within DoD. Over \$70 billion per year of support (almost one third of the defense budget) is funded under DBOF, and over 300,000 civilian and military personnel are employed in DBOF activities. This section focuses on some key concepts used in budgeting support activities under DBOF and contrasts current DBOF policies with new policy proposals offered in the model.

In order to be included in the DBOF financial structure as a "business area," support functions must meet four criteria: i.) outputs can be identified; ii.) an approved accounting

system is available; iii.) customers can be identified; and iv.) benefit/costs of establishing a buyer-seller relationship can be evaluated. (DBOF Handbook [1995]) Business areas include logistics activities that distribute, maintain and replace materiel to give combat units the equipment and support services they need, when they need them. Examples of DBOF business areas include: supply management, including the purchase, maintenance, storage, repair, and transportation of supplies and equipment; financial and accounting services; publications services; commissaries; information services; and some research and development.¹⁴

The purpose of DBOF was to "more closely relate the support infrastructure with the force structure" and to "improve the delivery of support services... while reducing the cost." (DBOF Handbook [1995]p.1-1) Four specific objectives are cited in the DBOF Handbook: (1) to "identify the full cost of support;" (2) to "measure performance on the basis of cost/output (i.e. unit cost) goals;" (3) to "reduce DoD support costs through better business practices;" and (4) to "foster efficiency and productivity improvements." (p.1-3) Each objective is briefly discussed below.

(1) *"Identify the full cost of support"*: The ultimate goal is to reveal all labor, materials and capital costs that contribute to each output of a given support activity at as disaggregated a level as possible. This increased cost visibility is designed to facilitate the cost accounting required to derive cost-based transfer prices "charged" to customers of DBOF activities.

The full cost of support includes civilian labor, military labor, material, and other direct costs, depreciation expenses, property maintenance, and "acceleration of labor" (i.e. the cost of fringe benefits). In a multi-product organization, the development of activity-based costing (ABC) can help to identify the full cost of support.¹⁵ (Brimson [1991]) For ease of exposition, the model focuses on support functions that produce at least one measurable output to which all relevant costs can be assigned.

(2) *"Measure performance on the basis of cost/output (i.e. unit cost) goals"*: Dividing a support activity's total costs in one period by the output produced that period yields an average total cost measure. Analogous to the accountant's constant unit cost assumption, under limited

(or asymmetric) information, this average total cost measure can be used as an estimate of the unit cost of support in a subsequent period.

"Organizations financed through DBOF sell goods or services to 'customers' with the intent of recovering the total cost of providing those goods and services." (DBOF Handbook [1995]p.2-1) This can be accomplished in two ways: First, through direct budget authority based on unit cost targets, or second, by allowing the activity to "earn" its budget through sales to customers at (transfer) prices which cover its costs.

In the first case, budget authority is provided equal to a support activity's total yearly output multiplied by its unit cost target. In this case the unit cost target set by OSD as the regulator of an activity could be thought of as the price paid by OSD as the final customer of that activity's product. This is particularly useful in the case where support activities offer significant "positive externalities." For example, when benefits are not completely captured by individual customers and "spill-over" to the DoD as a whole (e.g. like joint US-International defense management education), such activities can be "centrally funded" (using unit-cost-based price targets) by a single "customer" (such as OSD) who acts as a representative for the larger interests of DoD as a whole.¹⁶

The second case reflects current DoD policy as represented by DBOF. In this case, rather than support activities receiving unit-cost-based budget appropriations, customers (i.e. operational commands) request budgets to accommodate their support purchases. In turn, support activities are authorized to sell their outputs to customers at regulated cost-based transfer prices designed to cover their total costs. Unit cost goals can then be used as a measure of efficiency by comparing "actual unit cost experience against planned corporate expectations." (DBOF Handbook [1995] p.3-16)

(3) "*Reduce DoD support costs through better business practices*": Within business areas, support organizations (providers) operate like commercial businesses, selling goods and services to customers. Customers establish their requirements and are charged for the cost of the products or services provided.¹⁷ Thus DBOF providers "earn" their budgets based on the

quantity of goods and services they sell. Under DBOF, customers—typically combat or operating units—fund their requests with appropriations from Congress (i.e. with Procurement, Operations & Maintenance (O&M), and/or Research, Development, Test & Evaluation (RDT&E) money). The expectation is that "when these costs are... visible to the operating forces they will... make better resource allocation decisions in determining the levels of support they require for day-to-day operations." (Maroni [1993]p.3) Thus DBOF creates a "business" (or "customer-provider") relationship between military operating forces and support organizations. More importantly, it helps to link mission operations with the cost to support those operations.

Military Departments and Defense Agencies that have business areas financed under DBOF are responsible for the day-to-day management and operation of their respective business areas. However, when it comes to setting transfer prices, "[t]here are few restrictions by actual statute on DBOF activities in the establishment of rates." (Isosaari [1996]p.19)

The Military Departments establish prices with oversight provided by the Office of the Under Secretary of Defense (Comptroller) (OUSD(C)).¹⁸ Since OUSD(C) has oversight responsibility for generating unit-cost-based transfer prices, it effectively acts as the price regulator for support activities. Another assumption of the model is that the Comptroller (OUSD(C)) regulates transfer prices with the objective of encouraging cost reductions over time.

(4) "*Foster efficiency and productivity improvements*": A primary difference between DBOF business areas and private firms is that, by Congressional statute, DBOF activities must operate on a cumulative, non-profit (or "break-even") basis. Thus, activities financed under DBOF sell their goods and services to customers with the sole intent of recovering the total cost of providing those goods and services: "DBOF businesses strive to break even in prices charged to customers." (DBOF Handbook [1993])

However, as a DBOF business area sells goods or services, it earns revenues. The difference between revenues from sales and the ac-

tual costs incurred at any point in time is called the "Net Operating Result" (NOR). In general, during budget execution, a business area's NOR will either be positive (indicating profits) or negative (indicating losses). The "Accumulated Operating Result" (AOR) is the ultimate profit or loss realized from the operations of the business activity. Ideally, DBOF prices are set to achieve an AOR in the budget year of zero (see DBOF Handbook [1995]).

According to the DBOF Handbook [1995]: "[R]ates must be adjusted by the activity's manager to offset prior year gains or losses, thereby achieving zero net profit and loss." (p.20) Thus activities are penalized with tougher targets (i.e. lower prices) for cost reductions that lead to a positive NOR. The struggle to break-even can lead to inefficient behavior. In a recent study, Pavia [1995] emphasizes that unit-cost-based transfer pricing alone may not be sufficient to induce providers to lower costs. (p.1061) In the absence of further cost controls (e.g. from detailed regulations, organizational incentives, or the threat of competition), DBOF activities' lack of a profit motive could "lead to large losses, taking years to recoup, and may lead to unusually high rates that may cause the alienation of valued customers." (Friend [1995]p.4) Since losses lead to price increases in subsequent years, as rates climb, further reductions in customer demand could force providers to spread fixed costs over fewer units, thus driving prices up even higher, eventually leading to what Friend [1995] has called the "death spiral." (p.5) One "... complaint about DBOF has been the rapid boosting of... rates." (Friend [1995]p.11) However, the DBOF Handbook [1995] emphasizes that: "the primary responsibility of DBOF activities is to provide services and products to its customers at the lowest cost." (p.21)¹⁹

This paper offers a new framework that helps address these issues. The model combines unit-cost-based transfer pricing with two organizational incentive programs designed to foster efficiency and productivity improvements: "gain-sharing" and "success-sharing".

Under "gain-sharing," a portion of any surplus (or "profits") due to cost-reductions is rebated to the activity in the form of employee bonuses, extra vacation time, etc. Under "suc-

cess-sharing," rather than cutting future transfer prices to eliminate "accumulated profits," prices are ratcheted down to reflect a part, but not all of the cost reductions achieved. Thus, while success-sharing allows customers to benefit from cost reductions, it also rewards support activities with part of the future stream of benefits from their cost-reducing innovations. A useful, if imperfect analogy (and a possible way to distribute benefits derived from gain-sharing and success-sharing) is offered by current compensation practices familiar to some public sector wage earners. Gain-sharing would be similar to a (one-time) lump-sum bonus or a "merit increase," while success-sharing would be comparable to a performance-based promotion to a higher wage category or a "step increase" (a permanent increase in wage).

The next section introduces a model which illustrates analytically the incentives created by gain-sharing and the more potent incentives offered through success-sharing. The results of the model indicate that when support activities can invest in one period to lower their unit costs in a subsequent period, gain-sharing is a necessary, but not sufficient condition to create the incentives for them to do so. Success-sharing may be required to augment gain-sharing in order to encourage cost reductions over time.

THE MODEL

Assuming that "the primary responsibility of DBOF activities is to provide services and products to its customers at the lowest cost" (DBOF Handbook [1995]p.21), this section models a new budgeting approach for the Department of Defense. The objective of the model is to develop an incentive structure for internal support activities that rewards cost-savings and efficiencies. The model combines cost-based transfer pricing with the popular business practice of gain-sharing, and a new incentive program we call "success-sharing." Gain-sharing and success-sharing programs encourage support activities to lower costs by offering the opportunity to reward employees for cost-reducing innovations.²⁰

The DoD Comptroller (OUSD(C)) currently has oversight responsibility for cost-based transfer prices set under DBOF. The Comptroller "finalizes and approves the stabilized rates

that business activities may charge customers in a Program Budget Decision (PBD)." (Friend [1995]p.7) As a consequence, the Comptroller is modeled as a regulator (or "planner"), who sets maximum allowable transfer prices charged by sole providers of "core" support outputs.

The Comptroller's underlying objective in the model is to motivate activities to uncover and exploit cost-reducing innovations. The Comptroller offers gain-sharing and success-sharing programs, and regulates unit-cost-based transfer prices, to reward unit-cost reductions over time. Meanwhile, support activities seek investment strategies in unit-cost-reducing innovations that maximize the discounted present value of their rewards from gain-sharing and success-sharing programs, while simultaneously satisfying customer demands. The analysis begins with a discussion of the "principal's" (i.e. Comptroller's) problem, and then focuses on decisions taken by the "agents" (i.e. support activities). The model reveals conditions under which agents are likely to carry out the principal's objectives.

The model assumes each business area consists of a single support activity that produces one primary output, Q , to which all relevant costs can be assigned (where Q refers to the quantity of output or "workload" i.e. the number of units produced and sold per period). If the total cost function is given by $TC(Q)$, then $TC(Q)/Q = C(Q)$ are average total (or "unit") costs, while marginal costs are given by $TC'(Q) = MC(Q)$.

Each activity is assumed to operate somewhere on the economist's standard "U-shaped" (quadratic) unit cost function, $C(Q)$.²¹ The unit cost function has a unique minimum at Q^* , where: $C'(Q^*) = 0$. Moreover, since $C''(Q) > 0$, for all Q : at output levels $Q < Q^*$, unit costs decrease in Q (i.e. $C'(Q) < 0$); while at output levels $Q > Q^*$, unit costs increase in Q (i.e. $C'(Q) > 0$). Finally, since $C'(Q) = (1/Q)[MC(Q)-C(Q)]$: *marginal costs* are below unit costs when $Q < Q^*$; above unit costs when $Q > Q^*$; and the same as unit costs when $Q = Q^*$. The model focuses on three possibilities. An activity can operate: i) on the decreasing portion of its unit cost function (where $Q < Q^*$ and $MC(Q) < C(Q)$); ii) at the minimum point (where $Q = Q^*$ and $MC(Q) = C(Q)$); or iii) on the increasing portion of its unit cost function (where $Q > Q^*$ and $MC(Q) > C(Q)$).

The model assumes that cost saving measures (i.e. unit-cost reducing investments) un-

dertaken by an activity in the previous period, $t-1$, result in some quantifiable, permanent reduction in the *entire unit-cost function* in the current period, t , as well as in all subsequent periods. In this model, changes in output (or sales), Q , result in movements along the unit-cost function, $C(Q)$, while (past) investments in unit-cost reductions, say I_{t-1} , lower the entire unit-cost function i.e. cost-reducing investments translate into the same unit-cost savings for any output level, Q . Thus, the cumulative stock of unit-cost savings achieved by t , say K_t , acts like a shift parameter on the initial unit-cost function, $C(Q)$, lowering the entire function by the amount K_t , but preserving the minimum point at Q^* . (also see Sweeney [1981])

Suppose the Comptroller allows activity managers to invest, I_t , each period in whatever alterations to the production process they choose in order to generate bonuses through gain-sharing and success-sharing.²² Unit-cost savings are assumed to occur only after some initial investment, $I_0 > 0$, takes place (i.e. the initial stock of unit-cost savings is zero, $K_0 = 0$). In order to launch cost saving efforts, the Comptroller could offer seed money, I_0 , at time $t = 0$, and allow the activity to invest what it chooses, I_t , in each subsequent period.

According to the DBOF Handbook [1995], it is the responsibility of the management of each DBOF business area to "Identify and justify. . . those improvements which will produce future gains in effectiveness and efficiency." (p.2-9) These improvements (or "cost-reducing innovations") could be as simple as minor workplace modifications that boost morale, or as complex as labor-saving (management education, worker training, etc.) and/or capital-saving (adopting new software or internet applications or EOQ inventory policies, etc.) technical changes in the existing production process.

It is also stated that capital investments to finance these changes must "increase the utility of existing assets for more than one accounting period, or. . . substantially increase operating efficiency over more than one accounting period." (DBOF Handbook [1995]p.3-11) The model assumes that investments undertaken by the activity in the past period, I_{t-1} , result in some permanent, quantifiable operating efficiency, $f(I_{t-1})$, captured as a (lagged) increase in the stock of cost savings, $K_t - K_{t-1}$, that lowers the entire unit-cost function for all subsequent periods. (also see Sweeney [1981]) Thus the

change in the stock of unit-cost savings from any period $t-1$ to t is given by:

$$K_t - K_{t-1} = f(I_{t-1}); \text{ where } f'(I) > 0. \quad (1)$$

Equation (1) represents the evolution of unit-cost savings as a function of cost-saving investment in the previous period. The model assumes that past investment, I_{t-1} , translates into cost reductions, $f(I_{t-1})$, that add to the (permanent, cumulative) stock of unit-cost savings achieved over time i.e. $K_t = K_{t-1} + f(I_{t-1})$. Moreover, with $K_0 = 0$, writing, $K_t = \sum_{j=0}^{t-1} f(I_j)$, reveals that K_t is simply the cumulative stock of all unit-cost savings achieved up to time $t-1$.

Recent DBOF procedures established for capital budgeting (DBOF Handbook [1995]) suggest the Comptroller may have some historical basis for understanding the process described by (1). Note that K_t consists of a historical stream of unit cost savings (i.e. $K_t = f(I_0) + \dots + f(I_{t-1})$) made up of individual unit-cost "success stories," $f(I_j)$, that are (in principle) observable.

The cumulative impact of cost reductions on the initial unit cost function, $C(Q)$, is similar to that which might result from (and, in fact, could originate from) combining a "learning curve" with the original unit cost function. The cumulative stock of unit-cost savings, K_t , acts like a shift parameter on the initial unit-cost function, $C(Q)$. For example, the unit cost in period $t-1$, for any output level Q , is given by $C(Q) - K_{t-1}$. However, the investment, I_{t-1} , lowers unit costs in the next period, t , by $f(I_{t-1})$, to $C(Q) - K_{t-1} - f(I_{t-1}) = C(Q) - K_t$. In the model, cost-reducing investments lower the entire unit-cost function, but preserve the minimum point, Q^* . A useful avenue for future research is to examine the implications of cost-reducing investments that shift the minimum point, Q^* (i.e. that lower the cost function and simultaneously: increase the point of minimum efficient scale (or "full capacity")—a shift to the right; or reduce the point of minimum efficient scale (or "full capacity")—a shift to the left).

It is reasonable to assume that the Comptroller does not know the precise shape of an activity's unit cost function. For example, the Deputy Comptroller of DoD, Alice Maroni [1993], reveals that "In developing the FY1993 defense budget, DBOF rates were established... (and customer accounts were sized)... based on the best judgement that could be made at that time... [However] [w]e

have much to learn about the workload, cost, and revenue trends being experienced. . . ." (p.4)

Under such limited (or "asymmetric") information it is common for "[p]lanners. . . [to] use recent performance as a . . . basis for setting future indicators." (Weitzman [1976]p.253) Thus, an important simplifying assumption is that future transfer prices are developed from prior year unit cost experience. Given this scenario, and following Vogelsang & Finsinger [1979] and Sappington & Sibley [1988], support activities' cost and output data in the model are assumed to be revealed to the Comptroller (price regulator) with a one-period lag. As a consequence, the Comptroller (price regulator) sets a stabilized transfer price for each period, P_t , partly based on last period's unit costs, $C(Q_{t-1}) - K_{t-1}$.

Under current DBOF policy, "[r]ates remain in effect for a fiscal year to be used to bill the customer for work or service." (Isosaari [1996]p.20) Thus, the Comptroller sets a stabilized price, P_t , for a support activity's output for a given fiscal year, t , and then holds that price constant during the year of execution. This "stabilized rate" policy was originally designed "to protect appropriated fund customers (operating forces) from unforeseen cost changes and thereby enable customers to more accurately plan and budget for DBOF support requirements." (DBOF Handbook [1995]p.3-8) However, the fact that transfer prices remain unchanged over the fiscal year delivers another advantage. This so-called "regulatory lag" opens the door for a gain-sharing initiative to reward cost savings. According to Rogerson [1994]: when the ". . . regulatory adjustment of prices in response to cost reductions. . . lag[s] behind the actual achievement of cost reductions [this] creates an incentive for cost-efficiency." (p.65)

Since unit cost information in the model is revealed to the regulator with a one-period lag, the potential exists for a support activity to generate a surplus (or "profit") by driving its actual unit costs below the stabilized transfer price, P_t , during the period of regulatory lag. According to Laffont & Tirole [1993], Rogerson [1994] and others, in situations where the agent (the support activity) has better information than the principal (the regulator) about costs, it will generally be optimal for the principal to offer the agent a contract (e.g. gain-sharing) that leaves the agent with some economic profit (or "surplus"), in order to give the agent an

incentive to reduce costs. Thus, combining gain-sharing with a "stabilized" unit-cost-based pricing policy can encourage the constructive exploitation of regulatory lags.

According to Rogerson [1994]: "[a] general theme of the principal-agent literature is that in situations with asymmetric information, incentive schemes which cause the agent to reduce costs often necessarily also leave the agent with economic profit... This suggests... [the] creation of efficiency incentives. [For example], using incentive schemes such as regulatory lag that leave profit to the agent may be a particularly desirable policy for DoD to consider." p.76 (also see Demsetz [1968], Laffont & Tirole [1993], and Riordan [1993]).

Thus, combining cost-based transfer pricing and gain-sharing incentives with regulatory lags offers one approach to help overcome the principal-agent problem. This "incentive scheme" rewards extra revenues to support activities who are successful in achieving cost savings, i.e. in cutting actual unit costs below the previous period's unit costs—or below the regulated price, P_t . For the remainder of the paper, the term "surplus" (as opposed to "profits") will be used to describe these extra revenues. The objective is to distinguish earnings derived from cost-reducing innovations (i.e. "surplus"), from presumably less desirable earnings (i.e. "profits") that might be extracted from an internal organization's monopoly (or market) power, or from some other scheme.

Gain-sharing initiatives allow an activity to retain a fraction ($g \in [0,1]$) of any surplus, say S_t , earned through unit-cost reductions in a given year, t . The activity's gain-sharing bonus (gS_t) is the fraction of any surplus the support activity is entitled to retain, and to distribute internally, to reward cost savings. The remainder, $(1 - g)S_t$, are actual savings (to DoD) for the Fiscal Year.

The smaller the Comptroller sets the gain-sharing parameter, g , the greater the share of savings (surplus) that accrues to DoD, but the less incentive the support activity has to reduce costs and generate those savings. Conversely, the larger the Comptroller sets the gain-sharing parameter, g , the lower the share of savings that accrue to DoD, but the greater the incentive the support activity has to reduce costs.

Consider two extremes. With 100 percent gain-sharing ($g = 1$), the support activity retains all its cost savings (for employee bonuses, etc.), and there is no immediate gain to DoD.

Alternatively, with no gain-sharing ($g = 0$), it will be demonstrated that there is still no gain to DoD in the model, since there is no incentive for cost savings to occur over time. In the latter case (although monitoring "performance" is not formally modeled), if the Comptroller sets $g = 0$ and then attempts to "impose" lower unit cost targets (or cut transfer prices unilaterally), the Comptroller is likely to incur more burdensome monitoring costs to insure forced savings are not achieved at the expense of quality, or through "cost-shifting" or through some other "creative scheme."

Brief experiments in DoD with so-called "productivity gain-sharing" returned up to 50 percent (i.e. $g = 0.5$) of cost savings to the activity responsible.²³ (see Alderman [1993], Orvis, et.al. [1992], and Shycoff [1992]) However, according to the then acting Comptroller: "[t]he remainder of the savings will remain in the DBOF or operating budget and will be reflected in the next fiscal year's unit cost goals and price reduction to the customers." (Don Shycoff [1992]p.3) Thus, under productivity gain-sharing, beating the unit-cost-based price target earned support activities a share of current year cost savings, but made the target harder to beat in subsequent years.

In contrast, "success-sharing" shares the success of any permanent cost savings between customers and the activity responsible for those savings. Under success-sharing, while customers might still enjoy the benefit of new lower prices, the regulator does not lower prices to the full extent of the cost-savings achieved. This leaves support activities with future unit-cost (price) targets that are easier to beat than they might otherwise have been. As a consequence success-sharing tends to encourage further cost savings. Success-sharing initiatives (represented by the parameter, $s \in [0,1]$) are designed to share the permanent (cumulative) unit-cost savings, K_t , between customers and the activity responsible for those savings.

The Comptroller is assumed to set (or regulate) transfer prices each period, P_t , based on past (observed) unit-costs, $C(Q_{t-1}) - K_{t-1}$, modified to account for (expected) unit-cost savings, $f(I_{t-1})$, generated from the most recent (observed) investment, I_{t-1} , with an allowance for success-sharing. Thus the stabilized price an activity can charge for each unit of output over the period t , is given by,

$$P_t = C(Q_{t-1}) - (1 - s)K_t; \quad (2)$$

where: P_t consists of the original unit cost function, $C(Q_{t-1})$, adjusted for the (cumulative) downward shift in unit-cost savings, $K_t = K_{t-1} + f(I_{t-1})$, plus whatever allowance is made for success-sharing, sK_t .

The smaller the Comptroller sets the success-sharing parameter, s , the lower the price to customers, but the less incentive the support activity has to reduce costs. Conversely, the larger the Comptroller sets the success-sharing parameter, s , the higher the price to customers, but the greater the incentive the support activity has to reduce costs in subsequent periods.

Consider two extremes. With 100 percent success-sharing ($s = 1$), regulated transfer prices are permanently "stabilized" and never reflect any investment in cost savings. In this case, the Comptroller shares all subsequent (permanent) unit-cost savings with the support activity responsible, leaving customers without the benefit of lower prices. Alternatively, in the usual case of no success-sharing ($s = 0$), after a one-period lag, regulated transfer prices always fully reflect any unit-cost savings achieved. However, while a small s grants immediate benefits (price relief) to customers, the support activity does not have as large an incentive to invest in cost-reducing innovations, and thus long-term savings may be disappointing (i.e. to customers, DoD, Congress, or taxpayers).

The Comptroller's underlying objective in the model is to develop an incentive structure that motivates activities to invest in cost-reducing innovations that lead to permanent cost-savings. The Comptroller offers gain-sharing (g), success-sharing (s), and regulates unit-cost-based transfer prices, P_t , to encourage unit-cost reductions over time. In turn, support activities seek an investment strategy to reduce their unit costs over time, such as to maximize their returns (or share of the "surplus") from gain-sharing and success-sharing programs. The remainder of this section will focus on a support activity's response to the combined incentives of the unit-cost-based transfer pricing rule (equation (2)), gain-sharing (g), and success-sharing (s).

The last condition imposed on the support activity in the model is a requirement to satisfy demand at the regulated price. Most regulated public utilities face a similar mandate. A sup-

port activity must produce the quantity of output demanded by its customers at the unit-cost-based regulated transfer price set by the Comptroller. Assuming that a customer's demand for the support activity's output is sensitive to price, the relationship between the price charged and the quantity demanded from the activity becomes an important component of the analysis.

The means by which customers justify and obtain resources from DBOF activities is through DoD's Planning, Programming, and Budgeting System (PPBS). Once transfer prices are established, then customers determine how much support they will purchase at those prices. Resources required by customers to purchase business area products are subsequently identified in budget request document. "[C]ustomers determine the amount of goods and services they expect to purchase. . . and prepare their budget documents based on the projected rates and prices for those goods and services." (DBOF Handbook [1995])p.3-6

Here we are concerned with activities whose ("natural" or internal) monopoly position would, in the absence of regulatory oversight (or unit-cost-based transfer pricing), allow these activities to independently determine the (monopoly) price they could charge customers for their product. The study of industrial organization suggests that as the product price increases, less is demanded by customers of firms with market power. For example, in the case of repairs "[a]s. . . prices climb, operating unit commanders [i.e. customers] who have limited funds available may economize and reduce the number of units submitted for repair." (Friend [1996]p.5)

Thus, while a support activity must satisfy demand at the regulated price, the quantity demanded of a support activity's output is generally sensitive to that price. The demand function that captures this relationship can be written in two different ways: either as,

$$Q_t = F(P_t); \text{ or as, } P_t = F^{-1}(Q_t) \equiv D(Q_t); \quad (3)$$

where: $D'(Q_t) < 0$. In the model, it is convenient to follow the economist's convention and use the latter, "inverse demand function," to represent customer demand. In the case where de-

mand is set exogenously by policy-makers, and is thus insensitive to price, the demand equation in (3) is said to be perfectly "inelastic."

Faced with the Comptroller's binding regulatory pricing constraint (equation (2)), and a quadratic unit cost function, say $AC(Q) = C(Q) - K$, a support activity seeks investments in cost-reducing innovations (governed by (1)), that satisfy customer demands (according to (3)) and maximize returns from gain-sharing (g) and success-sharing (s). Rewards from gain-sharing in any period, t , are given by gS_t ; where S_t is the surplus earned during the period of regulatory lag.

The activity's surplus in the model is the difference between its total revenues (price times quantity sold) and its total costs (which include production and investment related expenses). Alternatively, the total surplus, S_t , consists of the "profit" generated on each unit sold, multiplied by actual sales, minus the total organizational costs of current investment. The amount of profit generated on each unit sold is the difference between the stabilized unit-cost-based transfer price, P_t , that the activity is allowed to charge its customers over the period of regulatory lag, and the actual (or realized) unit cost of producing each unit, $C(Q_t) - K_t$. However, multiplying the per-unit-profit, $P_t - [C(Q_t) - K_t]$, by actual sales, Q_t , yields only part of the total surplus, S_t . Investments in cost-reducing innovations and organizational costs associated with those investments need to be subtracted out.²⁴ These costs are captured by the investment cost function, $h(I_t)$, where: $h'(\cdot) > 0$, and $h''(\cdot) > 0$.

The support activity can make a surplus over deficit or break even over the period of regulatory lag, depending on whether or not it covers all of its costs when it charges the regulated unit-cost-based transfer price, P_t . These costs include production costs as well as investment costs. Thus, the surplus function in any period t can be written as:

$$S_t = P_t Q_t - [C(Q_t) - K_t] Q_t - h(I_t); \quad (4)$$

The first term on the RHS of (4) represents earned revenues, or the allowed price times the actual quantity sold. The second term on the RHS of (4) represents actual total production costs, or the actual unit costs incurred (in brack-

ets) times the quantity sold. The last term, $h(I_t)$, is an investment cost function that reflects diminishing returns to cost-reducing investments. It is designed to capture the organizational (or "total system") cost of adopting new technologies (e.g. actual investment costs, together with any training costs, morale problems, etc.) to reduce its future unit production costs.

In the model, the Comptroller regulates transfer prices according to equation (2), and offers gain-sharing (g) and success-sharing (s) incentive programs that reward cost-reductions over time. An activity's rewards from gain-sharing is given by gS_t ; where $g \in [0,1]$ reflects the share of the surplus, S_t (given by equation (4)), that the Comptroller decides to reward during the period of regulatory lag. Meanwhile, an activity's rewards from success-sharing depend on the new price, P_t (given by equation (2)), set at the end of each period (or fiscal year), where $s \in [0,1]$ reflects the share of the unit-cost savings the Comptroller decides to allow the activity to keep in future periods.²⁵ The next section models a support activity's response to this incentive structure.

THE SOLUTION

The support activity's objective is to choose an investment strategy to generate cost-reductions over time, that maximizes the discounted present value of its gain-sharing and success-sharing returns from its future stream of surpluses, while simultaneously satisfying customer demands. More formally, the activity's problem is to maximize,

$$W = \sum_0^{\infty} \{g / (1 + r)^t\} S_t; \quad (5)$$

where: the surplus at any time, t , is given by,

$$S_t = P_t Q_t - [C(Q_t) - K_t] Q_t - h(I_t); \quad (4)$$

the (inverse) demand the activity must satisfy is,

$$P_t = D(Q_t); \quad (3)$$

the regulated transfer price charged by the activity and set by the Comptroller is,

$$P_t = C(Q_{t-1}) - (1 - s) K_t; \quad (2)$$

the change in the stock of unit cost savings from past investment decisions is,

$$K_t - K_{t-1} = f(I_{t-1}); \quad (1)$$

gain-sharing and success-sharing parameters set by the Comptroller are, respectively, $g \in [0,1]$ and $s \in [0,1]$; and the rate at which a support activity discounts the future is given by, $r \in [0,1]$.

While this problem is too complex to obtain a complete analytical solution, useful insights can be derived from studying the (long-run) stationary equilibrium. To solve for the stationary equilibrium, it is useful to focus on the output consequences of an activity's investment decisions.

The connection between an activity's investment choices and the resulting output consequences is intuitive and fairly immediate. From equation (1), investment decisions translate into cost-reductions that are eventually captured, in equation (2), as regulated prices. In turn, the price charged by an activity impacts customers' demands for the output through equation (3). As a consequence, any investment strategy essentially has an output counterpart. While, in principle, either output or investment can be used for purposes of obtaining stationary equilibrium results, in practice, solving the model in terms of output requires considerably less assumptions. In any case, the stationary equilibrium is achieved at some stationary equilibrium output level, say Q_E , when no further cost-reducing investment is initiated.

Given the properties of the objective function together with the constraints, the first order condition requires that, at the optimum, for any two periods t and $t+1$, the increased profit from a small increase in output one period should be just offset by the discounted loss of profit in the subsequent period, or

$$dS_t/dQ_t + (1/(1+r))(dS_{t+1}/dQ_t) = 0. \quad (6)$$

In order to investigate the implications of the first order condition given by (6), the support activity's surplus function, S_v , given by (4), must be written exclusively as a function of output, i.e. Q_{t-1} , Q_t , and Q_{t+1} . (see equations (4a&b) in Appendix 1) This requires two further simplifying assumptions. First, changes in the stock of cost savings are assumed to be a fraction ($a \in [0,1]$) of past investment, I_{t-1} , or

$$K_t - K_{t-1} = f(I_{t-1}) = aI_{t-1}. \quad (1')$$

Second, the investment cost function in the surplus equation, (4), is given a functional form that reflects diminishing returns to cost-saving investments, or

$$h(I_t) = (1/2) b I_t^2; \text{ where } b > 0, \text{ and } h', h'' > 0. \quad (4')$$

Together, these two assumptions yield an expression for (6) exclusively in terms of output (see Appendix 1),

$$B(Q_{t-1}, Q_t, Q_{t+1}, Q_{t+2}) = 0. \quad (7)$$

Meanwhile, substituting (3) into (2), and using (1'), investment can also be written exclusively in terms of output (see Appendix 1),

$$I_t = (1/a)(1/(1-s))\{[C(Q_t) - C(Q_{t-1})] - [D(Q_{t+1}) - D(Q_t)]\}. \quad (8)$$

The stationary equilibrium output level is given by $Q_E = Q_{t-1} = Q_t = Q_{t+1} = Q_{t+2}$. It is immediately clear from (8) that, once the stationary equilibrium output level, Q_E , is attained no further cost-reducing investment will occur. At that point, the marginal (organizational) costs of any (further) investment outweighs the marginal benefits from gain-sharing and success-sharing.

At the stationary equilibrium, condition (7) can be written more explicitly as,

$$B(Q_E) = [g/(1-s)(1+r)]\{s(1+r)[MC(Q_E) - MR(Q_E)] - rC'(Q_E)Q_E\} = 0, \quad (9)$$

where: $MC(Q_E) = [C(Q_E) + C'(Q_E)Q_E]$ are marginal production costs (based on the original cost function, $C(Q)$), and $MR(Q_E) = [D(Q_E) + D'(Q_E)Q_E]$ is the marginal revenue from sales, Q_E .

From (9), as long as an activity is offered some amount of gain-sharing and success-sharing (i.e. with $g \in (0,1)$ and $s \in (0,1)$), if future returns are treated the same as immediate returns (i.e. with a discount rate, $r = 0$), the model solution is analogous to the usual static optimization result for any profit-maximizing firm with market power. Notably, the optimal stationary equilibrium output level, Q_E , is attained where marginal cost equals marginal revenue (i.e. where $C(Q_E) > MC(Q_E) = MR(Q_E)$). The difference from the static result is that, with

initial output, $Q^0 < Q^*$, and with $D'(Q) < C'(Q) < 0$, from (2a&b) in Appendix 1, at the stationary equilibrium, the cumulative stock of unit-cost-savings is $K > 0$. Thus, with $r = 0$, an activity's cost-reducing investments eventually drive its actual unit-costs down to $AC(Q_f) = C(Q_f) - K$; where Q_f satisfies $MC(Q_f) = MR(Q_f)$.

However, under the reasonable behavioral assumption that managers of support activities pay closer attention to near-term results, a positive time rate of discount ($r > 0$) is more appropriate. The remaining analysis focuses on this scenario.

Given a positive discount rate, it is useful to consider two reference points to help analyze the stationary equilibrium. The first reference point reflects the possibility the stationary equilibrium is at the initial point (Q^0, P^0), where the regulator first sets a price at which demand intersects the average cost function, or where: $P^0 = C(Q^0) = D(Q^0)$. The initial price, P^0 , is assumed to be set at a level such that it just covers the activity's initial cost per unit, $C(Q^0)$, of satisfying the resulting demand (Q^0), or $P^0 = C(Q^0) = D(Q^0)$. A second useful reference point is the minimum of the unit cost function, Q^* (i.e. where $C'(Q^*) = 0$). From (9), the first reference point yields,

$$B(Q^0) = [g/(1-s)(1+r)]\{s(1+r)[MC(Q^0) - MR(Q^0)] - rC'(Q^0)Q^0\}, \quad (9a)$$

while the second reference point yields,

$$B(Q^*) = [gs/(1-s)]\{C(Q^*) - MR(Q^*)\}. \quad (9b)$$

Note from (9a&b), that gain-sharing is necessary for activities to invest in cost-reducing innovations. With $g = 0$, the result is always the same, i.e. $B(Q^0) = 0$ (and $B(Q^*) = 0$). As a consequence, without gain-sharing, the stationary equilibrium is simply the initial output level, Q^0 (i.e. $Q_f = Q^0$), and the corresponding stationary equilibrium price is simply the initial regulated price, $P^0 = C(Q^0) = D(Q^0)$. Moreover, from (2a&b) in Appendix 1, $K = [1/(1-s)][C(Q^0) - D(Q^0)] = 0$, or in other words, the stock of cost savings at the stationary equilibrium is zero. The implication is that, without gain-sharing, it does not pay to invest in cost-reductions. Thus, gain-sharing is required for cost-reducing investment to occur in the model. As a conse-

quence, the analysis that follows assumes some degree of gain-sharing, i.e. $g > 0$.

From (9a&b) it is possible to narrow the analysis of stationary equilibria down to three cases. Each case is defined according to where an activity first operates on its initial unit cost function, $C(Q)$. An activity can operate: (1) on the decreasing section of its unit cost function (where $Q < Q^*$ and $C'(Q) < 0$); (2) at the minimum point (where $Q = Q^*$ and $C'(Q) = 0$); or (3) on the increasing section of its unit cost function (where $Q > Q^*$ and $C'(Q) > 0$).

It is an empirical question where an activity finds itself on its initial unit cost function. If an activity's unit costs decrease with output (or "scale"), then it enjoys so-called "economies of scale" (see Case (1)). In contrast, if an activity's unit costs increase with output (or "scale"), then it suffers from "diseconomies of scale" (see Case (3)). Strikingly different results are obtained from gain-sharing in these two cases. A summary of the model results (when $g > 0$ and $r > 0$) is presented below, and in an accompanying series of graphs. Details of the calculations can be found in Appendix 2.

Case (1): (See Figure 1)

If an activity initially operates at some point, $Q^0 < Q^*$, on the declining section of its unit cost function (where $C'(Q) < 0$), gain-sharing alone can motivate the activity to drive its costs down over time. The activity benefits by investing in cost-reductions, taking advantage of the regulatory lag in price adjustments.

Thus, in the absence of success-sharing (i.e. with $s = 0$), gain-sharing alone can motivate activities to invest in cost reductions. The cumulative stock of cost-savings at the stationary equilibrium is, $K_{s=0} > 0$. These investments eventually drive the activity to operate at the minimum point, $Q_f = Q^* > Q^0$, of a lowered unit-cost curve, $AC(Q) = C(Q) - K$. At the stationary equilibrium, Q^* , the price is given by, $P_{s=0} = D(Q^*) = AC(Q^*) = MAC(Q^*)$; where: $MAC(Q) = AC'(Q)Q + AC(Q) = MC(Q) - K$, is the marginal cost function associated with the lowered unit-cost function, $AC(Q)$.

In this case of decreasing unit costs (or "economies of scale"), combining the unit-cost-based pricing rule with gain-sharing alone, not only motivates activities to increase efficiencies and drive costs down over time, but also encourages production to con-

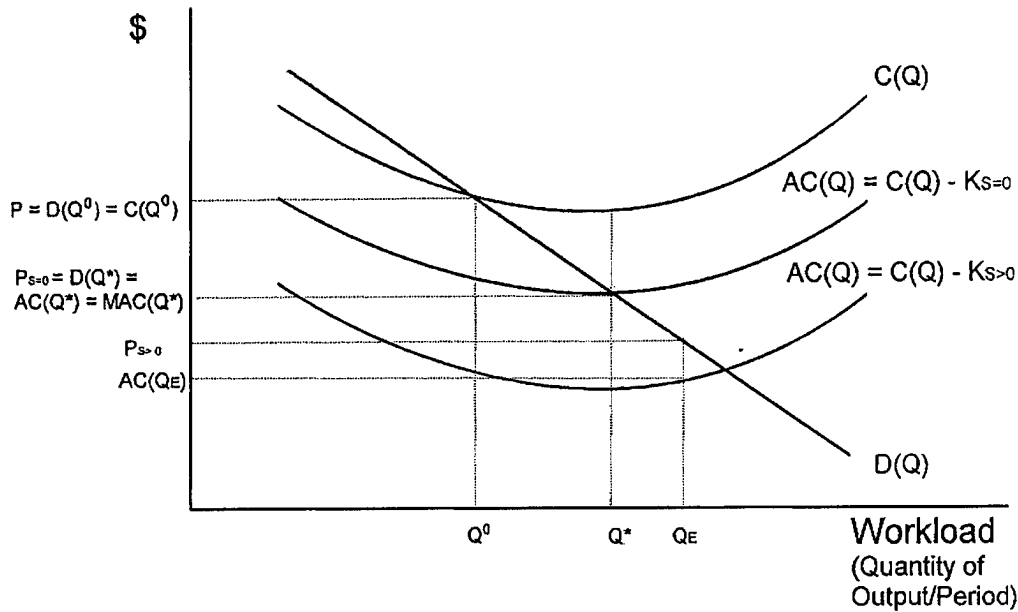


Figure 1.

verge to the economist's "full capacity" (or "minimum efficient scale"), where unit cost equals marginal cost. Thus, an additional advantage of combining the regulator's pricing rule (equation (2)) with gain-sharing ($g > 0$) is that unit-cost-based prices tend to automatically converge to preferred marginal-cost-based prices.

Nevertheless, any degree of success-sharing can promote even further cost-savings, i.e. at the new stationary equilibrium with $s = 0$, $Q_E > Q^* > Q^0$, and $K_{s>0} > K_{s=0} > 0$. It is useful to examine the impact of adding a success-sharing program from both sides of the organization—from the perspective of (internal) "customers," and from the perspective of (internal) "support activities."

From the point of view of customers, although unit costs are lower than they would be under gain-sharing alone, the price they pay is greater than actual unit costs, i.e. $P_{s>0} = D(Q_E) > AC(Q_E)$. However, from the activity's viewpoint, this price-cost difference can be thought of as the necessary (discounted stream of) rewards that motivates the search for further cost-savings. Regardless, customers still benefit from this new budgeting approach. They have more product available at the stationary equilibrium (i.e. $Q_E > Q^*$), and are charged a lower price (i.e.

$AC(Q_E) < P_{s>0} < P_{s=0} = AC(Q^*)$), than under gain-sharing alone.

Case (2): (See Figure 2)

If an activity operates at the minimum point, i.e. $Q^0 = Q^*$, where $C'(Q) = 0$, gain-sharing alone will not have an impact. At the stationary equilibrium, $Q_E = Q^0 = Q^*$, and $P_{s=0} = C(Q^0) = D(Q^0)$, so that the stock of cost-savings is, $K = 0$. In this case success-sharing is required to motivate an activity to invest in cost-reductions.

Combining gain-sharing with success-sharing can promote cost-savings. Similar to Case (1), from the customer's viewpoint, although unit costs are lower at the new stationary equilibrium ($Q_E > Q_0 = Q^*$) than under gain-sharing alone, the customer pays more than actual unit costs, i.e. $P_{s>0} = D(Q_E) > AC(Q_E)$. However, from the support activity's viewpoint, this price-cost difference can be thought of as the necessary (discounted stream of) rewards that motivates the search for cost-savings. Regardless, customers still benefit from the new budgeting approach. At the stationary equilibrium, customers have more product available, $Q_E > Q^*$, and pay less for it (i.e. $AC(Q_E) < P_{s>0} < P_{s=0} = C(Q^*)$).

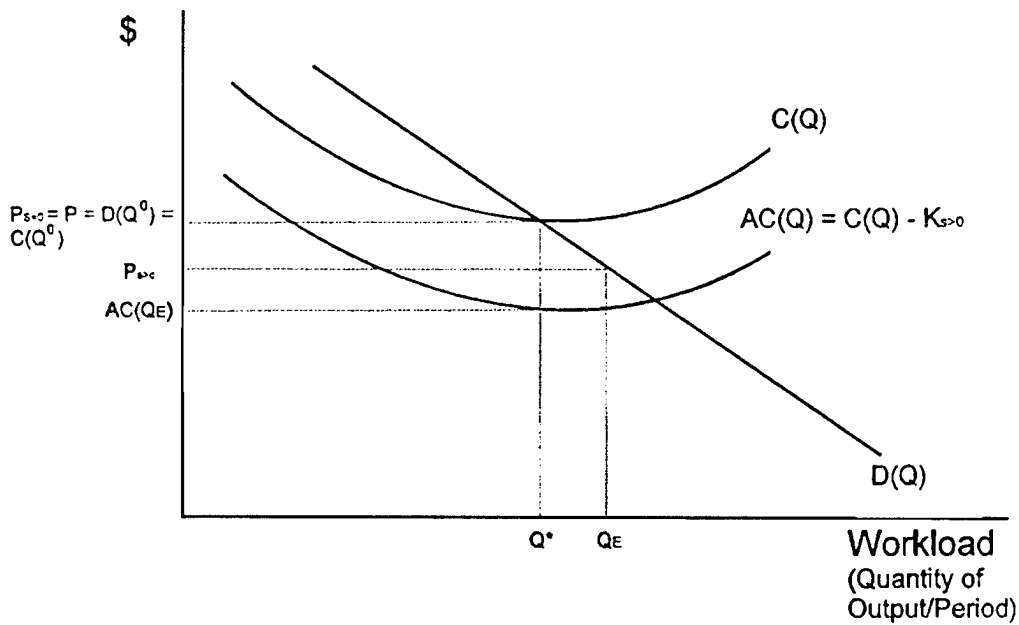


Figure 2.

Case (3): (See Figure 3)

Finally, if an activity initially operates at some point, $Q^0 > Q^*$, on the increasing section of its unit cost function (where $C'(Q) > 0$), even if gain-sharing is substantial (i.e. $g \rightarrow 1$), the threat of a subsequent collapse in the price (to

the new, lower unit costs) wipes out the activity's incentive to invest in cost-savings. (see Figure 4)

In fact, with gain-sharing alone, the only (notional) stationary equilibrium is one where $K < 0$. However, a negative stock of cost savings corresponds to an increase in unit-costs!

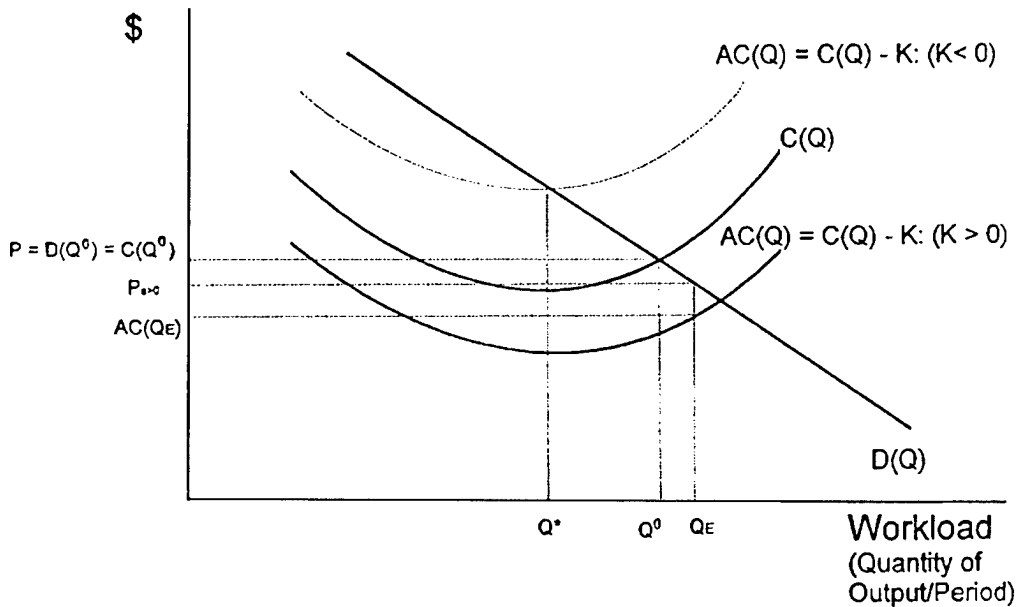


Figure 3.

GAIN-SHARING, SUCCESS-SHARING AND COST-BASED PRICING

Since the cumulative stock of cost savings is constrained to be non-negative in the model (i.e. cost-saving investment can only reduce unit-costs), gain-sharing alone does not yield a stationary equilibrium. In order to invest in cost-reductions, activities require a minimum amount of success-sharing.

The intuition for the results obtained in this case (when $g > 0$ and $s = 0$) can be seen using a simple example. Figure 4 illustrates a case where gain-sharing is not sufficient to induce an activity to invest in cost-reductions. If the activity produced 200 units last period (point A) at a unit cost of \$5/unit, suppose this is the price the regulator allows it to charge its customers during the current period.

Suppose cost-saving efforts drive the unit cost function in the current period from $C(Q)$ to $AC(Q)$. Then the unit cost of production is driven down to \$3/unit at point B. This would generate a maximum surplus during the period of regulatory lag equal to \$2/unit, or a total of \$400. If there is 50% gain-sharing (i.e. $g = .5$), then the maximum corresponding gain-sharing bonus is \$200, to be distributed to the employees at the end of the current period.

However, now suppose the regulated price the activity can charge in the next period drops

to the new unit cost level, or \$3/unit. Since the quantity demanded by customers is sensitive to the price, this new, lower price generates more demand (250 units) by customers (point C). This increase in quantity demanded implies that production costs per unit for the activity will rise to \$6/unit (point D), creating a \$3 loss on each unit sold (or a \$750 loss).

This means the activity manager faces a decision as to whether a \$200 bonus today is worth bearing a \$750 loss next period. To make the investment in cost-savings worthwhile to the activity, the discount rate would have to be an unrealistically high 275% (i.e. $200 \geq [1/(1+r)]750 \Rightarrow r \geq 2.75$). Even with 100% gain-sharing (i.e. with $g = 1$, such that the gain-sharing bonus equals the total surplus of \$400), the discount rate applied would have to be over 85% (i.e. $r \geq .875$). This simple illustration suggests that, while gain-sharing can be demonstrated to be effective where there are economies of scale, it may not be effective when there are diseconomies of scale.

Worse yet, with diseconomies of scale it is possible activities might have a perverse incentive to increase their unit cost function. If a zero-profit policy is pursued (where surpluses are used as bonuses, and losses are recouped by

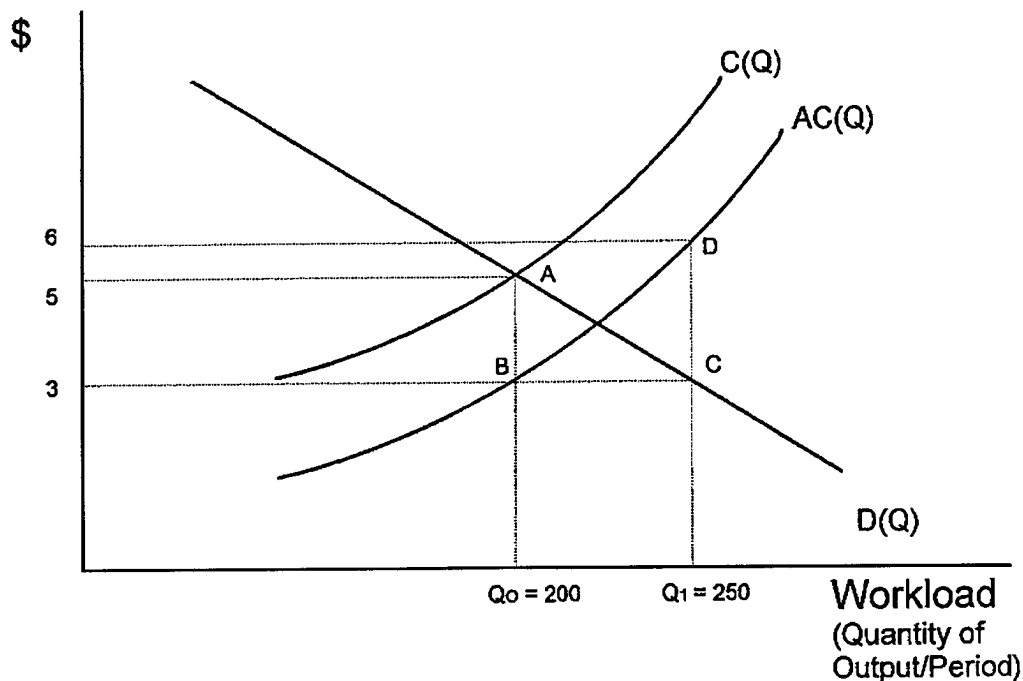


Figure 4.

adjusting future target prices), future target prices would reflect past losses. This means that the subsequent period target price would be the summation of the \$6 unit cost and an adjustment factor to recoup the \$750 total loss. This higher price would decrease the quantity demanded by the customer to a level perhaps even below the initial level of 200 units (i.e. to some quantity to the left of point A). A pricing system of this sort might either lead to instability, or perhaps as described in Appendix 2, to a stationary equilibrium at the minimum point, Q^* , on a higher unit cost curve, $AC(Q) = C(Q) - K$, where $K < 0$. This suggests that if gain-sharing is offered by itself, current DBOF pricing policy may need to be re-evaluated for those activities that operate under "diseconomies of scale" or "decreasing returns to scale."

One way to overcome this problem, and to induce managers to undertake cost-saving measures, is to prevent next period's target price from falling all the way to the new lower unit cost of production. This is precisely the concept behind "success-sharing." In the case of diseconomies of scale, although gain-sharing is necessary to motivate cost-savings over time, if offered by itself it can be counterproductive. A minimum level, $s[r/(1+r)]$, of success-sharing is required to attain a stationary equilibrium (i.e. $Q_t < Q^0 < Q^*$), where the stock of cost savings is, $K_{s,t-0} > 0$.

From the viewpoint of (internal) customers, although stationary equilibrium unit-costs are lower than starting unit-costs, $AC(Q_t) < C(Q^0)$, customers pay more than the new unit-costs, i.e. $P_{s,t-0} = D(Q_t) > AC(Q_t)$. However, from the activity's viewpoint, this price-cost difference can be thought of as the necessary (discounted stream of) rewards that motivates the search for cost-savings. Regardless, the final outcome under a combination of gain-sharing and success-sharing is favorable to the customer. More of the product or service is available, $Q_t > Q^0$, at a lower price than the starting price, i.e. $AC(Q_t) < P_{s,t-0} < P = C(Q^0)$.

CONCLUSION

This paper offers a new budgeting approach for the Department of Defense. The paper models an incentive structure for government activities that rewards cost-savings and efficiencies. The model combines cost-based-pricing with the popular business practice of

gain-sharing, and a new incentive program called success-sharing. The dual objective of the paper was: first, to offer a framework to help upper-level management evaluate organizational incentives in cost-based pricing systems; and second, to persuade the Operations Research community to join in this effort to model critical budgeting issues.

The goal of gain-sharing is to encourage activities to make an effort to reduce their current costs in return for some of the immediate gains from the cost savings. Success-sharing refers to the degree to which any "permanent" success in obtaining cost-savings is shared between customers and the activity responsible for the savings. While success-sharing allows customers to benefit from cost reductions, it also rewards support activities with part of the future stream of benefits from their cost-reducing innovations.

Many large, complex, vertically-integrated organizations include separate activities that conduct internal exchanges of goods and services. The challenge faced by these organizations is to govern the relationships among internal activities to promote the goals of the organization as a whole. Many private firms solve this problem through the use of internal cost-based transfer prices.

This paper applies lessons from the transfer pricing literature to a unique subset of government activities—those that "earn" their budgets. Internal DoD support activities financed through DBOF offer an illustration. DBOF activities sell their goods and services to "customers" (operating forces) at regulated cost-based transfer prices. The primary difference between DBOF business areas and private firms is that, by Congressional statute, DBOF activities must operate on a cumulative, non-profit basis. A critical challenge is to align agent's (or support activities') incentives, with the objective (e.g. cost-reduction) of the "principal" (or Comptroller).

This paper offers a new budgeting approach that encourages support activities to lower costs by offering the opportunity to reward employees for cost-reducing innovations. Economists have discovered that, both with defense firms and with electricity generating companies, regulatory adjustments of prices in response to cost reductions tend to lag behind the actual achievement of cost reductions, and that this can create an incentive for cost-efficiency. This concept of so-called "regulatory

lag" is applied here to the regulation of internal "support activities."

In the model, the "principal" (i.e. the Comptroller) offers gain-sharing and success-sharing programs, and regulates unit-cost-based transfer prices with a lag, to reward unit-cost reductions over time. Meanwhile, the "agents" (i.e. support activities) seek investment strategies in unit-cost reducing innovations that maximize the discounted present value of their rewards from gain-sharing and success-sharing, while simultaneously satisfying customer demands.

One extension of the model would be to develop an explicit game between the principal and the agent(s). In this game, one player, the principal (or Comptroller), chooses a pricing rule, the optimal period of regulatory lag, and gain-sharing and success-sharing programs, to maximize (the discounted present value of) total cost savings over time. Meanwhile, the other player, the agent (or support activity), would operate much as modeled here. The agent would take the pricing rule and regulatory lag as given, and would invest in cost-reductions to maximize the discounted present value of returns from gain-sharing and success-sharing programs, while satisfying customer demands.

This new budgeting approach, with its "built-in" incentive structure, rewards a share of revenues to activities who are successful in achieving costs savings over time. A recent Congressionally-mandated study emphasizes that: "[a] powerful incentive in the DoD would be to give Service Secretaries and heads of defense agencies the authority to retain in their future "top line" planning a substantial portion of any savings [or "surplus"] that can be generated in their department or agency" (DD [1995]p.4-16) This policy could ultimately encourage the implementation of gain-sharing and success-sharing programs at lower levels in the organization.

The results of the model indicate that when support activities can invest in one period to lower their unit costs in a subsequent period, gain-sharing is a necessary, but not sufficient condition to create the incentives for them to do so. Success-sharing may be required to augment gain-sharing in order to encourage cost reductions over time.

Three important results are obtained in the model. Each result depends on where an activity first operates on its initial unit cost function. An activity can operate: (1) on the decreasing

section of its unit cost function; (2) at the minimum point; or (3) on the increasing section of its unit cost function.

It is largely an empirical question where an activity finds itself on its initial unit cost function. If an activity's unit costs decrease with output (or "scale"), then it enjoys so-called "economies of scale" (Case (1)). In contrast, if an activity's unit costs increase with output (or "scale"), then it suffers from "diseconomies of scale" (Case (3)). Strikingly different results are obtained from gain-sharing in these two cases.

Given the current defense environment, a support activity may face a number of scenarios. Among these is: a) a cut in the demand for its product; b) increased competition from internal (or external) suppliers of a similar product; or c) an increase in demand for its product (say due to consolidation).

If an activity suffers significant cuts in demand for its output, it is more likely to fall under Case (1). The greater the actual (or threat of) competition, the more likely it is an activity operates at minimum unit cost, Case (2). Finally, if an activity experiences an increase in demand for its output, say due to consolidation, it is more likely to fall under Case 3. Regardless, in the absence of gain-sharing (i.e. with $g = 0$), it makes no difference where an activity operates on its initial unit cost function. There is no incentive for cost-savings in the model without some degree of gain-sharing.²⁷ In each case reviewed below, results are reported for gain-sharing alone, and then for a combination of gain-sharing and success-sharing.

Case (1): If an activity initially operates with decreasing unit costs, gain-sharing alone, combined with the regulated unit-cost-based transfer pricing rule, not only encourages activities to reduce costs over time, but also eventually results in marginal cost pricing. The activity benefits by investing in cost-reductions, because it can take advantage of the regulatory lag in price adjustments. In this case of decreasing unit costs (or "economies of scale"), combining the unit-cost-based pricing rule with gain-sharing alone, not only motivates activities to increase efficiencies and drive costs down over time, but also encourages production to converge to the economist's "full capacity" (or "minimum efficient scale"), where unit cost equals marginal cost. Thus, an additional advantage of combining the regulator's pricing rule with gain-sharing is that unit-cost-based

prices tend to automatically converge to preferred marginal-cost-based prices.

Nevertheless, any degree of success-sharing can promote even further cost-savings. From the point of view of customers, although unit costs are lower than they would be under gain-sharing alone, the price they pay is greater than actual unit costs. However, from the activity's viewpoint, this price-cost difference can be thought of as the necessary (discounted stream of) rewards that motivates the search for further cost-savings. Regardless, customers still benefit from this new budgeting approach. They have more product available and pay a lower price than they would under gain-sharing alone. An extension of the analysis might investigate whether offering gain-sharing alone leads to a bias in the composition of investment—favoring immediate (but more "transient") cost-savings, at the expense of future (but more "permanent") savings that are rewarded under a success-sharing program.

Case (2): If an activity operates at minimum unit costs, gain-sharing alone will not have an impact. However, combining gain-sharing with success-sharing can promote cost-savings. From the customer's viewpoint, although unit costs are lower at the new stationary equilibrium than under gain-sharing alone, the customer pays more than the actual unit costs. However, from the support activity's viewpoint, this price-cost difference can be thought of as the necessary (discounted stream of) rewards that motivates a search for cost-savings. Regardless, customers still benefit from the new budgeting approach. At the stationary equilibrium, customers have more product available and pay less for it.

Case (3): With increasing unit costs, even if gain-sharing is substantial, the threat of a subsequent collapse in the price (to the new, lower unit costs) wipes out the activity's incentive to invest in cost-savings. Gain-sharing alone does not yield a stationary equilibrium. In fact, in the case of "diseconomies of scale," offering gain-sharing by itself can be counterproductive.

In order to invest in cost-reductions, activities require a minimum amount of success-sharing. From the viewpoint of (internal) customers, although unit-costs with success-sharing are lower than starting unit-costs, customers pay more than the actual unit-costs. However, from the activity's viewpoint, this price-cost difference can be thought of as the necessary (discounted stream of) rewards that

motivates a search for cost-savings. Regardless, customers still benefit from the new budgeting approach. A combination of gain-sharing and success-sharing results in more of the product or service being made available, at a lower price to the customer.

Although combining gain-sharing and success-sharing with unit-cost-based pricing appears to offer an attractive alternative to conventional public budgeting, the manner in which such a system is implemented is critical to its success. A number of concerns remain to be addressed.

First, the model is silent about the depreciation of capital (either due to "wear & tear" or due to obsolescence). Adding depreciation would be a useful extension that would result in a steady state (investment plan), as opposed to the stationary state (in which there is no further investment) in the model. Another interesting opportunity to extend the model is to recognize that inaccurate forecasts of customer demands can impact other activities. The role of substitutes and complements and uncertainty in demand might be captured in a stochastic demand function. Other extensions could examine the impact of variable returns from cost-reducing investments, and explore the consequences of varying gain-sharing and success-sharing parameters over time.

A second concern is that the proposed budgeting system can only operate where organizational outputs, inputs, and customers are well defined. Moreover, a financial management accounting system is required that reveals all labor, materials and capital costs that contribute to each output at as disaggregated a level as possible. In the case of multiple outputs, any "common" or "joint" costs must be carefully allocated for the system to succeed in lowering overall costs. Moreover, in implementing this system, unit costs must include the (allocated) costs of the financial management accounting system itself, together with any required monitoring costs.

Third, to retain proper organizational incentives, the financial accounting system must be capable of separating exogenous cost changes from an activity's endogenous cost-savings. If exogenous (input) cost increases camouflage an activity's endogenous cost-savings, then incentives may not be awarded when they are in fact deserved. Conversely, if exogenous (input) cost decreases camouflage an activity's endogenous cost increases, then incen-

tives will be awarded when they are not deserved. Further complicating the problem is the fact external (or exogenous) costs are not constant over time. Introducing a stochastic unit cost function in the model could offer further insights.

Fourth, cost savings can clearly be generated by reducing quality. Thus, there may be burdensome monitoring costs (as well as some additional accounting costs) in insuring that claimed cost savings are not achieved at the expense of quality, effectiveness, or through "cost shifting," or through some other creative "rent-seeking" schemes. To avoid these problems, the threat of outsourcing, competition, or the explicit regulation and monitoring of performance, continue to be essential to safeguard quality and effectiveness.

Fifth, the incentive problem must be broken into two parts: i) the "external" incentives provided to the activity (through gain-sharing and success-sharing) to motivate cost savings, and ii) the internal distribution of those incentives to motivate management and workers. The important question of the distribution of internal incentives remains an issue for further study (see footnote 27).

Finally, the success of gain-sharing and success-sharing programs depends on public organizations benefiting from their cost-savings. Earning profits in the public sector is a sensitive and controversial issue. However, it may be useful to educate the public of the important role profits can play in motivating cost-savings. A few precedents could make this job easier. These include beneficial suggestion programs that offer both lump-sum (gain-sharing type) returns, and more permanent (success-sharing type) returns based on the savings enjoyed by an organization over time. Comparisons can also be drawn between employee compensation plans that offer productivity rewards as one-time ("lump-sum" or "annual") bonuses (similar to gain-sharing), as opposed to "step" or "merit" increases—which are permanent increases in salary (similar to success-sharing). Moreover, it may prove useful to use the term "surplus" instead of "profits." The term surplus can be used to distinguish earnings derived from cost-reducing innovations, from the presumably less desirable earnings (i.e. profits) that might be extracted from an activity's internal market power.

Increasing cost awareness and instilling business practices in public activities is an im-

portant first step. The next step is to grant activity managers the financial authority and flexibility to invest in manpower, equipment, and other resources to improve quality and lower costs, and to reward them for doing so.

In the private sector, savings result in increased profits or improved effectiveness—metrics for which managers are rewarded. In contrast, "[i]n the Federal sector... most rewards are for strict compliance with rules... [Thus], better organizational incentives are needed." (DD [1995]p.4-17) This paper offers a new budgeting approach with a "built-in" set of organizational incentives. The main conclusion is that, although customers still have to monitor quality, combining "gain-sharing" and "success-sharing" with a cost-based pricing system can motivate substantial cost-savings over time. Moreover, these results are not unique to Defense. The model applies to any regulated activities subject to unit-cost-based pricing.

APPENDIX 1

If a support activity is required to satisfy demand at the regulated price, then (3) can be substituted into (2) yielding expressions for this and next periods stock of cost savings in terms of output. These are respectively,

$$K_t = (1/(1-s))[C(Q_{t-1}) - D(Q_t)], \quad (2a)$$

and

$$K_t = (1/(1-s))[C(Q_t) - D(Q_{t+1})]. \quad (2b)$$

Substituting (2a&b) into (1') yields an expression for investment, I_t , in terms of output that can be given by (4), where $h(I_t) = (1/2)bl_t^2$. As a result of this and (1'), (2), (2a&b), and (3), surplus functions at t and $t+1$ can be written in terms of Q as follows:

$$S_t = D(Q_t)Q_t - Q_t\{C(Q_t) - (1/(1-s)) \cdot [C(Q_{t-1}) - D(Q_t)]\} - Z_t \quad (4a)$$

and

$$S_{t+1} = D(Q_{t+1})Q_{t+1} - Q_{t+1}\{C(Q_{t+1}) - (1/(1-s))[C(Q_t) - D(Q_{t+1})]\} - Z_{t+1}, \quad (4b)$$

where:

$$Z_t = (b/2a^2)(K_{t+1}^2 - 2K_t K_{t+1} + K_t^2),$$

and

$$Z_{t-1} = (b/2a^2)(K_{t+2}^2 - 2K_{t+1} K_{t+2} + K_{t+1}^2),$$

are functions of Q_{t-1} , Q_t , and Q_{t+1} , as a result of (2a&b). Using (4a&b) the condition given by (6) can now be expressed exclusively as a function of output, or as,

$$B(Q_{t-1}, Q_t, Q_{t+1}, Q_{t+2}) = 0. \quad (7)$$

APPENDIX 2

Given the initial price, $P^0 = C(Q^0) = D(Q^0)$, from (9a): with a success-sharing program (i.e. $s > 0$),

$$B(Q^0) \geq \text{or} \leq 0, \text{ as } s(1+r)[C'(Q^0) - D'(Q^0)] - rC'(Q^0) \geq \text{or} \leq 0; \quad (9a')$$

In the absence of success-sharing (i.e. $s = 0$), this condition reduces to,

$$B(Q^0) \geq \text{or} \leq 0, \text{ as } -rC'(Q^0) \geq \text{or} \leq 0. \quad (9a'')$$

Meanwhile, from (9b): with $s > 0$,

$$B(Q^*) \geq \text{or} \leq 0, \text{ as } [C(Q^*) - MR(Q^*)] \geq \text{or} \leq 0, \quad (9b')$$

where, $MR(Q^*) = D'(Q^*)Q^* + D(Q^*)$; while with $s = 0$, the condition reduces to,

$$B(Q^*) = 0. \quad (9b'')$$

The three cases analyzed below are distinguished by the location of the initial output level, Q^0 , relative to the minimum of the initial unit-cost function, Q^* : Case (1) examines $Q^0 < Q^*$; Case (2) examines $Q^0 = Q^*$; and Case (3) examines $Q^0 > Q^*$. In each case, the initial price is set where $P^0 = C(Q^0) = D(Q^0)$.

Case 1 ($Q^0 < Q^*$):

Suppose an activity operates on the declining portion of its unit cost function at some initial production level, $Q^0 < Q^*$, where $P^0 = C(Q^0) = D(Q^0)$, and that for any output level, $Q^0 \leq Q \leq Q^*$, $D'(Q) < C'(Q) < 0$. Two possible success-sharing scenarios need to be examined.

Case (1a): If $s = 0$, then it is immediate from (9a'') and (9b'') respectively that: $B(Q^0) > 0$ and $B(Q^*) = 0$. Thus, with no success-sharing, the stationary equilibrium is given by $Q_E = Q^* > Q^0$. Moreover, the fact that at Q^0 , $C(Q^0) = D(Q^0)$, combined with a monotonic decreasing (inverse) demand function and $D'(Q) < C'(Q) < 0$, $Q^0 \leq Q \leq Q^*$, implies that, $C(Q) > D(Q)$, $Q^0 < Q \leq Q^*$. As a consequence, associated with the stationary equilibrium, $Q_E = Q^*$, there is a positive stock of cost-savings, $K_{s=0}$ (i.e. from (2a&b) in Appendix 1, $K_{s=0} = [C(Q^*) - D(Q^*)] > 0$).

This indicates that gain-sharing alone (i.e. $g > 0$ and $s = 0$) is sufficient for cost-reducing investments to take place. The stationary equilibrium at $Q_E = Q^* > Q^0$ on the new lower average total cost curve, $AC(Q) = C(Q) - K_{s=0}$, is illustrated in Figure 1. Expressing the regulated price as $P = AC(Q) + sK$, reveals a stationary equilibrium price, $P_{s=0} = D(Q^*) = AC(Q^*)$.

It is useful to define the marginal cost function associated with the new lower unit cost curve, $AC(Q)$, as, $MAC(Q) = d[AC(Q)Q]/dQ = AC(Q) + AC'(Q)Q$. Since, at $Q_E = Q^*$, $AC'(Q^*) = 0$, the regulated price at the stationary equilibrium is set equal to marginal costs, (i.e. since $MAC(Q^*) = AC(Q^*)$). In this case, gain-sharing combined with a unit-cost-based transfer pricing rule not only encourages activities to reduce costs over time (i.e. $K > 0$), but, in the limit, also eventually results in marginal cost pricing of the output (i.e. $P_{s=0} = MAC = AC$).

Case (1b): If $s > 0$, since $D'(Q) < C'(Q) < 0$, $Q^0 \leq Q \leq Q^*$, from (9a'), $B(Q^0) > 0$. However, since $C(Q) > D(Q)$, $Q^0 > Q \leq Q^*$, from (9b'), it is also the case that $B(Q^*) > 0$. This implies that neither Q^0 nor Q^* are a stationary equilibrium. Thus, if it exists, the stationary equilibrium is at some output level, Q_E , beyond Q^* , such that $Q_E > Q^* > Q^0$. While gain-sharing alone is sufficient to encourage cost-savings, combining gain-sharing with success-sharing (i.e. $g > 0$ and $s > 0$) motivates further cost-reducing investment i.e. the stock of cost-savings with success-sharing is $K_{s>0} = [1/(1-s)][C(Q_E) - D(Q_E)] > K_{s=0}$ (i.e. the spread between $C(Q)$ and $D(Q)$ at Q_E is larger than at Q^* and $0 < s < 1$ implies $[1/(1-s)] > 1$). Moreover, the stationary equilibrium price is $P_{s>0} = D(Q_E) = AC(Q_E) + sK > AC(Q_E)$. Thus, in the model, further cost savings can be achieved if customers are willing to pay prices above unit costs at the stationary equilibrium. Finally, although marginal production costs at Q_E are greater than unit costs,

$MAC(Q_E) > AC(Q_E)$, the price, $P_{s>0}$, may or may not cover marginal costs, partly depending on the magnitude of success-sharing, sK (i.e. if success-sharing is sufficiently large, $P_{s>0} \geq MAC(Q_E) > AC(Q_E)$).

Case 2 ($Q^0 = Q^*$):

Suppose an activity operates at the minimum of its unit cost function at some initial production level, $Q^0 = Q^*$, where $P^0 = C(Q^0) = D(Q^0)$, and $D'(Q^0) < C'(Q^0) = 0$. Two possible success-sharing scenarios need to be examined.

Case (2a): If $s = 0$ and $Q^0 = Q^*$, then it is immediate from (9a'') and (9b'') respectively that: $B(Q^0) = 0$ and $B(Q^*) = 0$. Thus, with no success-sharing, the stationary equilibrium is given by $Q_E = Q^0 = Q^*$. As a consequence, while there is marginal cost pricing at the stationary equilibrium (i.e. $P^0 = MC(Q^0) = C(Q^0)$), since $K_{s=0} = [C(Q^0) - D(Q^0)] = 0$, even with a gain-sharing program (i.e. $g > 0$), if an activity currently operates at minimum unit costs, in the absence of a success-sharing program (i.e. with $s = 0$) there is no incentive in the model for investments in cost-reductions over time.

Case (2b): If $s > 0$ and $Q^0 = Q^*$, since $D'(Q^0) < C'(Q^0) = 0$, and $P^0 = C(Q^0) = D(Q^0) > MR(Q^0)$, then from (9a'), $B(Q^0) > 0$, and from (9b'), it is also the case that $B(Q^*) > 0$. This implies that neither $Q^0 = Q^*$ nor $Q < Q^*$ is a stationary equilibrium. Thus, if it exists, the stationary equilibrium is at some output level, Q_E , beyond Q^* , such that $Q_E > Q^0 = Q^*$. Since the stock of cost savings at this point is, $K_{s>0} = [1/(1-s)][C(Q_E) - D(Q_E)] > K_{s=0} = 0$, combining gain-sharing with success-sharing (i.e. $g > 0$ and $s > 0$) is required to motivate cost-reducing investment. Moreover, the stationary equilibrium price is $P_{s>0} = D(Q_E) = AC(Q_E) + sK > AC(Q_E)$. Thus, in the model, cost savings are achieved only if customers are willing to pay prices above unit costs at the stationary equilibrium. Finally, although marginal production costs at Q_E are greater than unit costs, $MAC(Q_E) > AC(Q_E)$, the price, $P_{s>0}$, may or may not cover marginal costs partly depending on the magnitude of success-sharing, sK (i.e. if success-sharing is sufficiently large, $P_{s>0} \geq MAC(Q_E) > AC(Q_E)$).

Case 3 ($Q^0 > Q^*$):

Suppose an activity operates on the increasing portion of its unit cost function at some initial production level, $Q^0 > Q^*$, where $P^0 = C(Q^0) = D(Q^0)$, and that for any output level, $Q^* \leq Q \leq Q^0$, $C'(Q) > 0 > D'(Q)$. Two possible success-sharing scenarios need to be examined.

Case (3a): If $s = 0$, then it is immediate from (9a'') and (9b'') respectively that: $B(Q^0) < 0$ and $B(Q^*) = 0$. Thus, with no success-sharing, if it exists, the stationary equilibrium is given by $Q_E = Q^* < Q^0$. However, the fact that at Q^0 , $C(Q^0) = D(Q^0)$, combined with a monotonic decreasing (inverse) demand function and $C'(Q) \geq 0 > D'(Q)$. $Q^* \leq Q \leq Q^0$, implies that, $C(Q) < D(Q)$,

$Q^* \leq Q < Q^0$. As a consequence, associated with the stationary equilibrium, $Q_E = Q^*$, there is a **negative** stock of cost-savings, i.e. $K_{s=0} = [C(Q^*) - D(Q^*)] < 0$. However, this implies the activity will invest to pad (or increase) its costs, and only cost-reducing investments are allowed in the model. So $Q_E = Q^*$ cannot be a stationary equilibrium. It is demonstrated in (3b) below that a minimum degree of success-sharing is required when an activity operates with unit production costs that increase with workload. Moreover, if a regulator has a pricing rule that compensates activities for cost increases, surplus-maximizing activities may have an incentive to make spurious "investments" when they operate under increasing unit cost conditions.

Case (3b): If $s > 0$, since $C'(Q) \geq 0 > D'(Q)$, $Q^* \leq Q \leq Q^0$, from (9a'), if $0 > s > [r/(1+r)]$, then $B(Q^0) > 0$. Meanwhile, since $C(Q) < D(Q)$,

$Q^* \leq Q < Q^0$, if the demand curve is sufficiently inelastic (i.e. customers are relatively insensitive to price), then $C(Q^*) > MR(Q^*)$, and from (9b'), it is also the case that $B(Q^*) > 0$. Marginal revenue at Q^* , $MR(Q^*)$, can be written in terms of the price elasticity of demand ($E_{Q,P} = (\% \Delta Q / \% \Delta P) = (D'/D) < 0$): $MR(Q^*) = D'(Q^*)Q^* + D(Q^*) = D(Q^*)[(1/E_{Q,P}) + 1]$, where inelastic demand is given by $|E_{Q,P}| < 1$. If these conditions hold, then neither Q^0 nor Q^* (nor any other arbitrary reference point, $Q^* < Q < Q^0$) are a stationary equilibrium. Thus, if it exists, the stationary equilibrium is at some output level, Q_E , beyond Q^* , such that $Q_E > Q^0 > Q^*$. Since the stock of cost savings at this point is, $K_{s>0} = [1/(1-s)][C(Q_E) - D(Q_E)] > 0$, combining gain-sharing with a minimum level of success-sharing (i.e. $g > 0$ and $s > [r/(1+r)]$) is required to motivate cost-reducing investment. Moreover, the stationary equilibrium price is $P_{s>0} = D(Q_E) = AC(Q_E) + sK > AC(Q_E)$. Thus, in the model, cost savings are achieved only if customers are willing to pay prices above unit costs at the stationary equilibrium. Finally, although marginal production costs at Q_E are greater than unit costs, $MAC(Q_E) > AC(Q_E)$, the price, $P_{s>0}$, may or may not cover marginal

costs partly depending on the magnitude of success-sharing, sK (i.e. if success-sharing is sufficiently large, $P_s > 0 \geq MAC(Q_T) > AC(Q_T)$).

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ENDNOTES

¹ See, for example, W. Rogerson's paper entitled "On the Use of Transfer Prices Within DoD: The Case of Repair and Maintenance of Depot-Level Repairables by the Air Force," *Logistics Management Institute Paper PA303RD1*, March 1995.

² Stiglitz [1986] offers the following example. Suppose there is cost-based pricing where the allowed price for the service provided by a government activity is the cost per unit of the service. Suppose further that performance is difficult to measure; and that the government activity attempts to maximize its budget. Assuming demand for the service is inelastic over some range (i.e. that demand is relatively insensitive to price increases), it would pay a monopoly activity "to **increase the degree of inefficiency** until the price (costs per unit of delivered service) were increased to [the budget maximizing price]." (p.173)

³ Outsourcing involves "using federal funds to pay a private company to do defense work" while privatization "completely transfers [a DoD activity] to the private sector." (SECDEF Annual Report [1996] p.125)

⁴ The defining choice of any firm or organization is to "make-or-buy" required intermediate products. The "buy" options include open market purchases or supplier contracts (outsourcing). The "make" option entails "ownership integration" of support services. The make-or-buy decision defines the boundaries of the organization. These management choices rely heavily on the "transactions costs" litera-

ture. (Shugart, et. al. [1994]) Transactions costs consist of (1) search and information costs, (2) bargaining and decision costs, and (3) policing and enforcement costs. The choice of whether to purchase inputs in markets, to contract with suppliers, or to internalize the transaction depends on the marginal benefits and costs of each alternative. Relying on outside suppliers or markets involves price searches, quality concerns and security issues. Contracting with specific suppliers involves negotiations and the writing and enforcement of contracts. Meanwhile, a primary challenge of ownership integration is the "principal-agent" problem. Principals (upper-level management) need to align the interests of their agents (lower level managers and workers) with their own. One approach is to create an incentive structure that rewards efforts that help accomplish the principal's goals, but this necessarily includes the (costly) monitoring of performance. This paper models a specific incentive structure designed to motivate agents (support activities) to accomplish the goal of achieving cost savings and efficiencies over time.

⁵ While Secretary of Defense Perry agrees that "outsourcing [certain] commercial activities [such as depot maintenance and material supply management] holds promise to streamline DoD support activities and to achieve cost savings," he concludes "the Department must carefully evaluate the extent to which we can achieve efficiencies." (DoD News Release No. 470-95, 8/25/95) Meanwhile, the Commission acknowledges that, where there are "... difficulties in structuring appropriate contracts and establishing meaningful competition" (DD [1995] p.3-4), or where government activities depend on specialized, defense-unique resources (DoD Handbook [1995]), outsourcing may even be counterproductive. Moreover, expanding the DoD's use of contract support also "requires improving its abilities to create and administer those contracts, and to monitor contractor performance." (DD [1995] p.3-3) Another issue that remains is the current legislation that mandates a 60-40 split of support work between DoD and private contractors.

⁶ A recent example is provided by the British Government's attempt to regulate its newly privatized electric utilities ("How to Privatize,"

The Economist, 3/11/95). When a support activity cannot be competitively outsourced, and cannot be competitively supplied in-house, it may still be possible to control the activity via price regulations similar to Britain's so-called RPI-x method. (see "Incredible," The Economist, 3/11/95) There, a regulated price is established and allowed to rise by no more than the retail price index (RPI) less some percentage, x . When the price cap's time is up, the regulator sets a new one for the next period. Under this system a regulated activity profits directly from any cost savings, at least until the next review. Britain's regulations essentially allow activities 100% gain-sharing for any cost savings achieved during the period the regulated price is in force. However, when a new cap is set, cost savings are passed on to consumers who receive the full benefits from the price dropping to the new lower cost level. So far the evidence suggests that cost-based price regulation combined with gain-sharing has "delivered lower real prices to consumers." ("Disgusted," The Economist, 3/11/95)

⁷ Although if success-sharing is to be implemented in future contracts for the contractor's benefit, then the DoD might consider sharing cost savings in the current contract (i.e. allowing contractors something less than 100% gain-sharing).

⁸ Another concern is that, with time-constrained purchases, the "ease" of a purchase begins to take precedence over its cost-effectiveness. Moreover, as the fiscal year comes to a close, instead of pooling savings remaining towards the end of the year at a more aggregate level and evaluating remaining funding priorities globally, each activity has an incentive to use its budget on its own list of priorities, leading to sub-optimal behavior. Increased oversight of activities (e.g. monitoring, auditing, rules and regulations) often occurs in response to problems such as these.

⁹ Schick [1988] cites the extreme case of Ireland where the government "maintain[s] year-round financial control... departments submit monthly spending plans at the start of the year and month-by-month comparisons of actual and projected expenditure during the year... underexpenditure in any month is treated as a saving for the year and normally is

not available for spending in a later month." (p.529)

¹⁰ The standard regulatory response also violates the National Performance Review's and Commission on Roles and Mission's goal to empower managers and workers at lower levels by decentralizing authority and encouraging them to become more entrepreneurial: "DoD managers at all levels must be empowered to make sound business decisions based on broad policy guidance, rather than on detailed rules." (DD [1995] p.3-6)

¹¹ If customers are given the freedom to choose between internal providers, or to "out-source," and/or if customers have the flexibility to spend their funds on a variety of inputs, this freedom and flexibility can encourage further efficiencies in customer purchasing decisions and generate competitive pressure on internal providers to lower costs and improve the product.

¹² This assumption is not as innocent as it sounds. As noted by Pavia [1995]: "[m]ulti-product firms usually incur fixed costs which are difficult to attribute to the production of a particular output. This is a troublesome issue for firms that use production costs to establish prices. [Whereas] firms may avoid the problem by only looking at directly attributable [variable] costs," (p.1060) this can pose serious difficulties. For example, if cost-based pricing is combined with gain-sharing, costs that are "counted" might be cut at the expense of those not counted, resulting in higher costs overall. A recent study by Rogerson [1995] offers sobering insights into problems that can arise under DBOF when costs are not assigned correctly in multiproduct organizations. Although not specifically addressed here, these problems merit further attention.

¹³ Historically, certain DoD support activities operated in so-called "revolving funds" that charged customers for products and services. The U.S. Military has used two primary types of revolving funds, stock funds and industrial funds. Stock funds were used to procure material and to hold inventory for resale to the operating forces, recovering only the cost of the material itself. Industrial funds provided services such as depot maintenance and transportation, recovering overhead costs in addi-

tion to material costs. The DBOF merged into one revolving fund, nine existing stock and industrial funds, along with five additional defense commercial operations or business activities previously funded with direct appropriated funds.

¹⁴ For detailed information on the composition and scope of each business area, see Appendix C of the DBOF Handbook [1995].

¹⁵ Activity-based costing (ABC) breaks down an organization into activities. The principal function of an activity is to convert resources (labor, materials, etc.) into outputs. While activities consume resources, customers consume activities. ABC systems: 1) identify the activities performed to produce outputs; 2) map the usage of organizational resources to these activities; 3) identify the outputs produced; and 4) link the activity costs to the outputs.

¹⁶ Alternatively, OSD could offer price subsidies that lower the price to in-house (DoD) customers. Also, to the extent internal costs exceed commercial rates, but in-house production is required to protect wartime mission capability, OSD could either explicitly subsidize the difference, or act as the final customer. A useful avenue for future research is to examine the role of subsidies in DoD.

¹⁷ Customers determine and justify their anticipated requirements for goods and services they acquire from the DBOF business areas. Resources required by customers to purchase business area products are subsequently identified in budget request documents. Budget documents are developed using projected rates and prices published by the DBOF business areas.

¹⁸ Final approved rate changes are established by the OUSD(C) and recorded in Program Budget Decision (PBD) documents: "For the DBOF business areas, the OUSD(C) reviews and approves all rates and prices developed. . . ." (DBOF Handbook [1995] p.3-12)

¹⁹ The "death spiral" problem results in so-called "pass-through" funding requests to Congress. However, pass-through funding was originally designed only as a onetime correction of the price structure to bring rates back down to a reasonable level. A conjecture is that

this problem will become progressively more acute under current DBOF regulations.

²⁰ The working hypothesis is that the provision of a clear link between a support activity's success in reducing costs (while preserving or increasing quality), and wages and job security, will motivate managers and employees to generate cost savings. The incentive problem can be broken down into two parts: i.) external incentives provided to the activity to motivate cost savings, and ii.) the internal distribution of those incentives to motivate management and workers. This paper focuses on external incentives and leaves the important question of the distribution of internal incentives as an issue for further study. However, an expert on the latter offers that "[o]nce 'statistical control' is established, serious work [by management] to improve. . . [the] economy of production can commence." (Deming [1986] p.354) This paper studies two specific external incentives designed to reward the "economy of production": namely gain-sharing and success-sharing.

²¹ This unit-cost function, $C(Q)$, is also assumed to be stable over time. This assumption is important because in reality, cost functions are stochastic and subject to exogenous (random) shocks in input prices. (Deming [1986]) If exogenous shocks (unforeseen resource price increases, natural disasters, wars, etc.) create cost increases which camouflage an activity's true cost saving efforts, then appropriate incentives may not be awarded to the activities when they were, in fact, deserved. Thus, if gain-sharing and success-sharing under unit-cost-based transfer pricing is to be successful, it must be possible for financial accounting systems to separate exogenous cost changes (e.g. higher fuel prices) from an activity's endogenous cost savings (e.g. a new inventory policy). Although not specifically addressed here, this more complex problem deserves further attention.

²² These cost-reducing innovations could be as simple as introducing modifications to the procurement process that allow credit card purchases and encourage the use of commercial specifications, to more involved changes that require rewriting rules & regulations governing travel, personnel actions, and part-time employment. In the model, it makes no difference whether cost savings result from an application

of new technology, improved employee cooperation and information sharing that reduces errors, rework and wasted materials, or from employee education and training.

²³ Orvis, et.al. [1992] offer an interesting review of one DoD gain-sharing experiment conducted at Sacramento's Air Logistics Center called PACER SHARE. Although difficult to evaluate, apparently "Sacramento display[ed] a tendency toward cost savings under PACER SHARE relative to its baseline, . . ." (p.121)

²⁴ In contrast to the way investment costs are treated in the model, under current DBOF policies, "[c]apital expenditures. . . for new capital assets. . . are financed through depreciation or capital surcharge rates included in prices." (DBOF Handbook [1995]p.3-11)

²⁵ Although g and s are fixed over time for purposes of the model, an interesting extension would be to examine the case where gain-sharing and success-sharing is not constant over time.

²⁷ In the case of DBOF, business areas are organizations within the department, and savings in DBOF business areas are savings in the department, and the savings result in increased operating revenue for the war fighters. Therefore, one might assume that public servants already have the motivation to seek cost-savings. However, due to the current price-setting

rules in DBOF and from the history of non-profits, our model assumes further cost-savings could be motivated through organizational incentives that offer something similar to a "profit motive." For example, one of the most striking changes taking place in business today is the dramatic reshaping of compensation plans. Incentive pay plans are rapidly spreading from the executive suite to the shop floor. Incentive pay plans set the compensation of workers and top management according to how well the company achieves a number of preset objectives. The most widely employed is profit- (or gain-) sharing, whereby employees receive annual bonuses based on corporate profit performance. More than 30% of US companies employ some form of profit- or gain-sharing. However, the design of an effective and fair incentive pay plan is a daunting challenge. Pay must be closely linked to performance measures that managers and employees can directly influence. Moreover, the marginal impact of each employee's effort must be separated from the influence of others and more general company-wide or economy-wide influences. Each of these considerations is relevant to the current model, and offers opportunities for future research. (also see Hirschey & Pappas [1995]p.339)