THE ALLOCATION OF MILITARY RESOURCES: IMPLICATIONS FOR CAPITAL-LABOR SUBSTITUTION

Richard V.L. Cooper and Charles Robert Roll, Jr.

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I. INTRODUCTION

The advent of a volunteer armed force, rising manpower costs, and tight defense budgets have all served to make military manpower one of the most important issues in defense planning and budgeting. Manpower costs have risen dramatically in recent years, both in total dollars and in their share of the U.S. defense budget. For example, personnel related costs for defense increased by 100 percent between 1962 and 1972; in 1962, manpower costs constituted 43 percent of the total U.S. defense budget; the 1972 figure is 54 percent.¹ Further, manpower costs are expected to continue to increase, while the total U.S. defense budget is expected to stay roughly constant in real terms for the foreseeable future.²

These trends have focused attention on the possible alternatives for reducing manpower costs. Manpower planners have traditionally taken manpower requirements as given and have therefore directed their efforts toward more

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² Similar trends have been witnessed in much of Western Europe. Between 1962 and 1972 personnel expenditures (and their share of the defense budgets) changed as follows: Italy, from 216 billion lire (30%) to 1061 billion lire (57%); West Germany, from 4,161 million DM (27%) to 11,236 million DM (46%); Great Britain, from £997 million (51%) to £1387 million (49%); and France, from 10,370 Fr million (54%) to 16,683 Fr million (47%). Rising manpower costs seem to be general to most of Western Europe as well as to the United States. See Atti Interni (1963); Atti Parlamentari (1972); Budget of the U.S. Government (1962, 1972); Le Budget de 1962, Le Budget de 1972; Statement on Defence, 1962; Statement on Defence Estimates, 1972; White Paper 1970...; White Paper 1971/1972....
efficient methods for achieving the "desired" enlistments and reenlistments. However, the costliness of these options has recently motivated defense planners to consider substituting other, less expensive, inputs for manpower. In particular, the notion of substituting non-labor inputs (i.e., capital) for labor in the military has generated considerable interest. The substitution of a fork-lift truck for warehousemen in a base depot is an example. Of course, the substitution between capital and labor is not one-sided: additional men can be used to replace machines.

Besides the pressure from increased military wages, the substitution of capital for labor is encouraged by the type of technological innovations that the American economy has traditionally produced. For a variety of reasons, the direction of innovative activity in the United States has tended to favor inventions that permit the substitution of capital for labor. The most frequently cited examples involve the automation of activities formerly performed by hand, not only for consumer items (e.g., washing machines), but also for industrial activity (e.g., computer-controlled lathes). These innovations are frequently adaptable to military use—in fact, some have been the product of military research and development.

Pressed on the one hand by rising manpower costs and lured on the other by labor-saving technical change, the obvious solution may seem to be the substitution of capital for labor in performing military missions. Unfortunately, the issue is not that straightforward. First, and perhaps most important, we must be concerned not only with the cost of labor but also with the cost of capital.

Second, as educational levels advance, training technologies improve, and technical innovations make labor more productive, the quality of military manpower rises. In such a situation, productivity increases may outstrip wage increases, and the rational policy might be to substitute labor for capital—i.e., more (or more highly skilled) men and less (or simpler) equipment. Third, as military wages have increased, so have civilian wages risen—but not as much. The substitution of civilian personnel for uniformed personnel must therefore be considered as well as the substitution of capital for labor. The civilianization of kitchen duties is a case in point. Finally, as wages have risen in general, wages for skilled personnel and unskilled personnel have not increased in the same proportions. As a result, the
substitution of unskilled labor, or unskilled labor and capital, for skilled labor must also be examined. The replacement of highly skilled aircraft maintenance technicians by less skilled personnel and replaceable (rather than "repairable") parts serves as an example.

To properly address these issues, an analytic framework is required. The issues put forth here all relate to the allocation of military resources among various inputs:

- capital and labor
- military and civilian labor
- skilled and unskilled labor

The framework must be sufficiently general to encompass this spectrum of issues, but at the same time it must be specific enough to provide guidelines to the actual allocation of resources among these inputs.

In addition to a conceptual framework, the trends mentioned earlier, such as rising manpower costs, should be placed into proper perspective. For example, although both labor and capital costs have risen, which has risen more? Only then can we hope to establish an appropriate set of policies to deal with the allocation of scarce military resources.

This paper presents, first, a conceptual framework for analyzing the efficient allocation of defense resources. Such a framework is necessary for the development of guidelines for more efficient management of military capital and manpower. Second, to put increases in military compensation and procurement costs into the proper perspective, we examine the historical trends in the cost of labor and the cost of capital. These trends can then be used to focus on the possible opportunities for savings.

Our broad purpose is to motivate defense planners to make input cost considerations an integral part of force planning. In each of the Services and in the Office of the Secretary of Defense (OSD), separate organizational entities determine the amount of manpower required (manpower) and how those requirements are to be filled (personnel). As a result of this distinction, manpower costs seldom enter as a criterion for determining the structure of the military force. Only when the individual requirements become aggregated into total Service budgets do planners begin to worry about costs. However, the lack of visibility of costs at the initial planning level results in gross
adjustments that cut force structure rather than reallocate resources. To ensure efficient allocation of resources, it is essential to consider costs of inputs in the early stages of force planning.
II. CONCEPTUAL FRAMEWORK FOR MILITARY RESOURCE ALLOCATION

The concept of the production function offers a useful analytic device for investigating the conditions for efficient allocation of military resources. In particular, guidelines for efficient manpower utilization can be developed from a careful analysis of the relationships between military inputs and outputs. These guidelines permit us to determine the importance of changes in the prices of inputs and how the military should respond to these changes.

THE PRODUCTION FUNCTION AND THE OPTIMUM ALLOCATION OF RESOURCES

The technological relationship between inputs and outputs is given by the production function—that is, the production function specifies the amount of output resulting from each alternative combination of inputs.\(^1\)

In its simplest form, the production function is commonly written in terms of primary (versus intermediate) inputs. The two-factor production function—with capital and labor as inputs—is a useful representation of the military production process.

The general two-factor production function may be given algebraically as

\[
Q = f(K, L) \tag{1}
\]

where

- \(Q\) = amount of output produced,
- \(K\) = amount of capital input, and
- \(L\) = amount of labor input.\(^2\)

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\(^1\) For a more thorough discussion of the issues related to the production function, see Samuelson (1947) and Solow (1955-1956).

\(^2\) In a less aggregated version, the production function could be written in terms of several different types of labor and capital inputs:

\[
Q = f(K_1, ..., K_n; L_1, ..., L_m), \tag{1a}
\]

where

- \(K_i\) = ith type of capital input, \(i=1, ..., n,\)
- \(L_i\) = ith type of labor input, \(i=1, ..., m.\)

The military planner may wish to consider the tradeoffs between highly skilled maintenance personnel and less highly skilled (and, hence, less costly) maintenance personnel. Such an examination follows easily from equation (1a).
The production function in equation (1) may be represented graphically as in Figure 1. Each of the curved lines in the (K,L) plane is an isoquant—that is, it represents a fixed level of output. Each isoquant shows the various combinations of the two inputs capable of producing the given output. The slope of the isoquant measures the rate at which capital and labor can be substituted for one another. Therefore, the curvature of the isoquants in Figure 1 has the intuitively appealing notion that as less and less of one input is used, it becomes increasingly difficult to further substitute for that input.

The production function, by itself, does not provide guidelines for the allocation of resources; it simply identifies the alternative combinations of technologically feasible inputs that achieve a given amount of output. Instead, guidelines for the efficient allocation of resources are the result of putting the production function into a cost framework. For a given
budget, the optimal allocation is the combination of capital and labor that maximizes output.¹

In the two-input model the total cost of using any combination of inputs can be written:

\[ C = rK + wL \]

where \( C \) = total cost, \( w \) = cost (per unit) of labor services, and \( r \) = cost (per unit) of capital services.

In the simplest case, the cost per unit of labor services is just the wage rate. That is, to purchase a unit of labor services a firm must pay the prevailing wage rate for those services. Although the current wage rate may be a reasonably good approximation of the cost of labor for most private firms, it is not adequate for the military. The cost of labor services to the military includes training costs, payments in kind (e.g., medical benefits), and substantial retirement benefits, as well as current wages. Therefore, a better approximation of the true wage rate for the military may be total personnel costs (including all of the above items) divided by the amount of labor services used by the military.

The cost of capital is somewhat more elusive. Further, the issue concerning the cost of capital has been confused considerably by the recent furor over military procurement cost overruns. This is not to say that they are unimportant, rather, the cost of capital includes more than just the cost of procurement.

The cost of capital means what would have to be spent to purchase a given amount of capital services, not what would have to be spent to purchase a piece of equipment. This distinction is important since capital renders services for many time periods, but procurement of a given piece of equipment occurs in only one period. It is this lack of coincidence between the time periods that causes the difficulty.² Since a piece of equipment is

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¹ It can be shown that the case of minimizing cost for a given output generates equivalent results.
² Note that this is not generally a problem with labor services, since labor is usually paid for its services at the time those services are performed.
not entirely used during the production process, the costs of using that equipment should reflect the costs of purchasing the services of that equipment, not the total cost of the equipment itself.

An alternative way of viewing the cost of capital is to think of it as what would have to be spent to "rent" a unit of capital. As procurement costs increase, the cost of capital services increases, since a more expensive piece of equipment is being rented. As the cost of borrowing funds (i.e., the interest rate) increases, the rental rate increases, since investors in equipment must be compensated for the forgone interest. As depreciation or obsolescence increases, the rental rate increases, since the equipment is amortized over a shorter length of time.

Since the military generally does not rent its capital, but instead purchases it, we must impute the rental rate on capital. The cost of capital is given by

$$ r_t = (d_t + i_t) P_t, \quad (2) $$

where $r_t =$ cost of capital in period $t$,
$d_t =$ depreciation rate of capital equipment in period $t$,
$i_t =$ money cost of borrowing (i.e., the interest rate) in period $t$, and
$P_t =$ relative price of capital equipment in period $t$.

Therefore, it is possible for the "cost of capital" to fall even when the purchase price is increasing. This can happen if either depreciation/obsolescence or the interest rate falls sufficiently. Thus, equation (2) indicates that the cost of capital includes more than just procurement costs.

Given the cost of labor ($w$), the cost of capital($r$), and the budget constraint ($B$), it can be shown that the conditions for optimization are

$$ \frac{\partial f}{\partial L} = \frac{w}{r}, \quad (3a) $$

$$ B - rK - wL = 0, \quad (3b) $$

where $\partial f/\partial L =$ marginal product of labor, and
$\partial f/\partial K =$ marginal product of capital.
Thus, output is maximized for the budget \( B \) when the budget is allocated between capital and labor such that the ratio of the marginal product of labor to the marginal product of capital\(^1\) equals the ratio of the cost of labor to the cost of capital. Since the ratio of the marginal product of labor to the marginal product of capital is a function of the capital-labor ratio \( (K/L) \), the optimal capital-labor ratio satisfies equations \((3a, b)\), as shown by the tangency between the isoquant \( Q \) and the budget line \((w/r)^*\) in Figure 1.

As the cost of labor services rises relative to the cost of capital services, the capital-labor ratio should be increased by substituting capital for labor. As a result, we should focus our attention on changes (past and expected) in the cost of labor relative to the cost of capital—not just on compensation and procurement costs.

**MILITARY PRODUCTION FUNCTION**

The production function illustrates the relationships between various combinations of inputs and the resultant outputs. In particular, the production function representation of the alternative ways of providing national defense is a useful abstraction of the military manager's problem. Conceptually, we could write down a production function of the type shown in Figure 1 and then apply the optimization techniques to obtain the least costly combination of military inputs to achieve the specified level of national defense (or, alternatively, to maximize defense effectiveness for a given cost). Unfortunately, in the real world, measurements of national defense outputs and military inputs are not easily made. In addition, the precise meaning of a "military production function" is not clear.

Since the production function relates quantities of inputs used to quantities of outputs produced, inputs and outputs must be given in terms of measurable quantities. Such quantities may be hard to come by in the case of providing national defense. Perhaps the most difficult conceptual problem is the definition of output. The production function framework presented in the last section generally takes output to be measured in physical units. Yet, how does one define units of national defense?

\(^{1}\text{This ratio is commonly referred to as the "technical rate of substitution of capital for labor."}\)
"National defense" is itself vaguely defined, so that it is virtually impossible to measure national defense output. Therefore, a major task in developing criteria for efficient allocation of military resources involves finding measurable quantities that can serve as proxies for national defense.

One method for dealing with the problem of defining national defense would be to categorize defense according to the various military missions that are part of national defense. That is, national defense can be decomposed into its separate military components. For example, one might think of the capability to destroy 1,000 tanks in a 90-day Central European war scenario, or the capability to deliver a given amount of bomb tonnage in Southeast Asia, or the capability to provide a given number of surveillance steaming hours in the Mediterranean. Therefore, rather than develop a production function for national defense, we can think of military production functions, where the military production function relates military inputs to military outputs (i.e., the "military mission"). This can be represented algebraically as:

\[ Q = f(M_1, M_2, \ldots, M_n), \]

where \( Q \) represents national defense and \( M_i, i = 1 \) to \( n \), represent the \( n \) different military missions. Each of these military missions can itself be thought of as a function of the capital and labor in that mission:

\[ M_i = g_i(K_i, L_i), \quad i=1, 2, \ldots, n, \]

where \( K_i = \) capital used in the \( i \)th mission, and
\( L_i = \) labor used in the \( i \)th mission.

It can be shown that the optimal allocation of defense resources between capital and labor is achieved when each mission is separately optimized.

\[ ^1 \text{Presumably, other factors, such as diplomatic skills, would also be a part of the production of national defense. However, our focus here will be on the military components of national defense.} \]
with respect to capital and labor usage, per equations (3a, b).¹ This enables us to examine the allocation of defense resources to capital and labor by way of the individual military missions. In fact, since the production function for national defense is just the combination of production functions for the specific missions, changes in the allocation of defense resources between capital and labor are a result of changing the allocation within the missions.

The production function given in equation (1) is directly applicable to the design of new military systems, for the designer is explicitly confronted by a vast array of alternative configurations of the system, each of which may embody different amounts of capital and labor. For example, in the case of a new naval vessel of some specified capability, subsystems for the ship (including support on shore) can each be designed to incorporate different levels of automation (capital intensity). Therefore, the designer faces the type of capital-labor tradeoffs shown in Figure 1 for the total ship, since the ship is just the sum of the various subsystems—each of which embodies different amounts of capital and labor. The optimum configuration is that for which the capital-labor ratio satisfies equation (3a). In other words, the least-cost solution is obtained when the isoquant in Figure 1 is tangent to the budget line.

The production function is also applicable to a broader range of problems—the allocation of military resources for existing systems. Generally, the military uses a variety of different systems in the course of fulfilling a specified mission. Further, different combinations of these systems can be used in the performance of a mission. Since these existing systems incorporate different capital-labor ratios, the capital-labor ratio for the mission can be changed implicitly by explicitly altering the mix of systems

¹The major condition that must be satisfied for this result to hold is that the missions must be aggregated such that the contribution of the capital and labor of one mission to the output of all others must be small. For example, if daytime and nighttime reconnaissance were managed as separate missions, then each mission commander would most likely require separate aircraft. However, since the same aircraft could be used for both missions (only requiring different cameras), the rule of aggregation suggests that these two activities should be managed as one mission.
used. That is, even if each system has a fixed capital-labor ratio, the usage of capital and labor in the mission can be altered by altering the mix of systems. To illustrate this, consider a hypothetical antitank mission in a 90-day Central European scenario. The mission may be performed by various combinations of close air support, helicopters, tanks, artillery, and infantry, among others. Each of these systems most likely embodies a different capital-labor ratio. The capital-labor ratio for the mission can be altered by using different combinations of these systems, even though the capital-labor ratio for each system might be fixed.

Given the production function for the mission, the optimal allocation of that mission's resources between capital and labor is determined by equations (3a, b). Therefore, the mission commander should select the capital-labor ratio for which the ratio of the marginal product of that mission's labor to the marginal product of that mission's capital equals the ratio of the cost of labor to the cost of capital.

RESPONDING TO CHANGES IN PRICES, TECHNOLOGY, AND DESIRED OUTPUT

The preceding discussion has centered on the allocation of military resources between capital and labor for given factor prices, technology, and desired military output. How should the military respond when some or all of these change?

The general response to a change in relative factor prices can be seen from a closer examination of equation (3a). Cost is minimized for a specified level of output when the technical rate of substitution of capital for labor equals the ratio of the cost of labor to the cost of capital. Since the marginal products of capital and labor are decreasing functions of the amounts of capital and labor used, the technical rate of substitution of capital for labor is an increasing function of the capital-labor ratio. Therefore, as the ratio of the cost of labor to the cost of capital increases (decreases), the capital-labor ratio should be increased (decreased) such that the technical rate of substitution of capital for labor equals the ratio of the cost of labor to the cost of capital. For example, if the ratio of the cost of labor to the cost of capital increases from (w/r)* to (w/r)** as in Figure 1, then the optimum capital-labor ratio increases from (K*/L*) to (K**/L**)—that is, by substituting capital for labor.
The above discussion relates to the amounts of physical units of inputs used. That is, if the cost of labor rises relative to the cost of capital, then capital should be substituted for labor--namely, the amount of physical units of capital used should be increased while the amount of physical units of labor used should be decreased. However, the amount of dollars spent on capital and labor, as a function of the ratio of the cost of labor to the cost of capital, depends on the elasticity of substitution of capital for labor. For example, if the elasticity of substitution of capital for labor is greater (less) than one, the share of the budget spent on labor will increase (decrease) with a rise in the ratio of the cost of labor to the cost of capital. Thus, the share of the budget allocated to labor could actually increase with a rise in relative cost of labor, even though fewer units of labor would be used. It is therefore misleading to focus solely on the share of the budget allotted to various inputs. Instead, our attention should be directed toward the relative costs of capital and labor and the elasticity of substitution of capital for labor.

Second, consider the relationship between the optimum capital-labor ratio and technological innovation. For a given ratio of the cost of labor to the cost of capital, the optimum capital-labor ratio increases with more labor-saving technological innovation, and conversely for capital-saving innovation. Since the American economy has tended to produce capital-intensive (labor-saving) technological innovations, we should expect the optimum capital-labor ratio to increase over time, other things equal.

Finally, how is the optimum capital-labor ratio related to the level of output? That is, should a larger force be more capital intensive or labor intensive?

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1. The elasticity of substitution of capital for labor is defined along the production function isocostant as the percentage increase in the capital-labor ratio resulting from a percentage increase in the ratio of the marginal product of labor to the marginal product of capital. If labor and capital are paid their marginal products (i.e., if \( w \) and \( r \) equal the marginal product of labor and capital, respectively), then the elasticity of substitution of capital for labor is given by:

\[
e = \frac{\Delta(K/L)}{K/L} \cdot \frac{\Delta(w/r)}{w/r},
\]

For example, if the efficient capital-labor ratio changes by one percent as a result of a one percent change in ratio of the cost of labor to the cost of capital, then the elasticity of substitution equals one.
intensive than a smaller force? The answer depends on both the ratio of the cost of labor to the cost of capital and the shape of the isoquants at different levels of output. In most analyses, the ratio of the cost of labor to the cost of capital is assumed to be insensitive to the level of output. However, this is not likely to be the case for the military since the supply of capital goods to the military is likely to be much more elastic than the supply of labor to the military. In other words, as the military seeks to purchase both more labor and more capital (to produce a greater military capability), the increased wage rate it will have to pay in order to attract sufficient numbers of additional volunteers is likely to be much larger than the higher price it has to pay for its increased capital purchases. Therefore, the wage-rental rate would be expected to increase for higher levels of output. On the other hand, we know little about the shape of the isoquants for different levels of output. If we assume that the shape of the isoquants is the same at different levels of output, then the optimum capital-labor ratio is likely to be larger for greater levels of military capability, since the ratio of the cost of labor to the cost of capital increases for larger amounts of output.

THE PRODUCTION FUNCTION AS A TOOL FOR ANALYSIS

The analytic framework presented here provides a useful method for examining the issues related to the allocation of military resources among various inputs. In particular, the following have been established:

- Military capability is directly related to the inputs used and, therefore, efficient management of military resources is achieved by choosing appropriate combinations of those inputs.
- The classification of inputs into two broad categories—capital and labor—is a useful device for examining alternative responses to such changes as rising manpower costs or rising procurement costs.
- The relevant costs are the cost per unit of capital services and the cost per unit of labor services. The cost of capital includes not only procurement costs but also the cost of borrowing funds and depreciation or obsolescence costs. The cost of labor to the military includes training costs, payments in kind, etc. as well as wage costs.
The optimum allocation of military resources between capital and labor is then a function of the relative costs of labor and capital. Thus, the optimum capital-labor ratio is an increasing function of the ratio of the cost of labor to the cost of capital.

To determine the appropriate allocation of military resources among inputs, we should focus our attention on changes in the relative prices of labor and capital and on the opportunities for substitution.

The aggregate production function framework developed earlier enables us to examine the evidence on capital and labor costs in a systematic manner and to prescribe general guidelines for more efficient management of defense resources. For example, both manpower costs and capital procurement costs have been rising. If the cost of labor has risen more than the cost of capital, then the appropriate response is to substitute capital for labor, not simply to cut the force size.
III. THE COSTS OF MILITARY CAPITAL AND LABOR: SOME EMPIRICAL EVIDENCE

Military managers have been confronted with various, and possibly conflicting, pieces of information with respect to the allocation of military resources. For example, the cost of labor to the military has risen markedly in recent years, but so has the cost of military procurement.

A general methodology for examining this allocation was developed in Section II. It was shown that "military capability" may be thought of in terms of the collection of military missions. Since the product of each mission is a function of the inputs used, "national defense" (the aggregate military production function) may be constructed in terms of the aggregate amounts of these inputs. It was then suggested that the classification of inputs into two categories—capital and labor—offers a useful conceptual tool for the military manager. In other words, an aggregate military production function may be written in terms of the total amounts of capital and labor used in the military. Therefore, if military resources are to be optimally allocated between capital and labor, the capital-labor ratio for the military should be an increasing function of the ratio of cost of labor to the cost of capital.

This framework indicates that the major cost variable of concern to the military manager is the ratio of the cost of labor to the cost of capital, not just manpower costs and procurement costs. Given the considerable confusion that has surrounded the issue of the costs of capital and labor, the true costs of these inputs must be identified to ensure the maximum effectiveness from scarce defense resources.

The cost of capital is an elusive concept that must be imputed since the Department of Defense (DoD) does not rent the services of capital equipment from year to year, but instead purchases its equipment. The method for imputing the cost of capital facing DoD was given by equation (2) and is reproduced here:¹

¹This definition of the cost of capital measures the cost to DoD, and not necessarily the cost to society of forgoing a dollar's worth of consumption or investment in the private sector. There are various concepts that
\[ r_t = (d_t + i_t) P_t, \]  

(6)

where \( r_t \) = cost of capital in period \( t \),
\( d_t \) = the rate at which the capital stock depreciates in period \( t \),
\( i_t \) = the money cost of borrowing in period \( t \), and
\( P_t \) = relative price index of military procurement in period \( t \).

Equation (6) simply says that the cost of utilizing a dollar of capital equipment in year \( t \) (expressed relative to some base year) is a function of the money cost to the government of borrowing, the rate of depreciation, and the rate of inflation in the prices of capital goods. However, each of these components of the cost of capital requires both explanation and estimation.

Our estimate of \( r_t \) is the rate of interest on three- to five-year government bonds. This rate of interest is the nominal money cost to the government of long term borrowing in any given year. Our estimate of \( P_t \) is the wholesale price index of machinery and equipment published by the Bureau of Labor Statistics (BLS). This index is obviously not a perfect price index for the military sector. However, since no military price index is available, we used this index because we assumed it most closely approximated changes in the prices of military goods. Other possible price indexes tend to be highly correlated with the machinery and equipment price index but also do not seem to be as suitable for estimating the prices of military goods.

Our estimate of the rate of depreciation is derived from estimates of the military capital stock in 1967 dollars and U.S. budget data on procurement expenditures deflated to constant 1967 dollars with the above BLS wholesale

have been proposed to measure the opportunity cost of investing in the public sector. These measures can differ from our definition of the cost of capital. In this paper we have not addressed the issue of society's efficiency versus DoD's efficiency but have simply undertaken an examination of the factor costs that would influence internal DoD efficiency.
price index used as the deflator.\footnote{Details of the capital stock estimate may be found in Cooper and Roll (1973) and with slightly revised figures in a forthcoming paper by the authors. The basic estimating procedure which was followed was to take annual data from Real and Personal Property of the Department of Defense and adjust these inventory data on military equipment in use, supply system inventories and production for (1) changes in coverage and (2) the valuation of military equipment in use at acquisition cost and thus with a mixture of vintages of historical prices. These results are estimates; nevertheless, we feel that they give a reasonably accurate picture of the year-to-year changes in the level of the military capital stock. We have focused on military equipment; military construction and research and development are not included.} For each year our estimate of the rate of depreciation was calculated as the following:\footnote{Derived from the relationship between the capital stock in two adjacent years and the level of investment:}

\[ \delta_t = 1 - \frac{(K_t - I_t)}{K_{t-1}} \]

where \( \delta_t \) = the depreciation rate estimate for \( d_t \),
\( K_t, K_{t-1} \) = are estimates of the capital stock in years \( t \) and \( t-1 \), and
\( I_t \) = the amount spent on procurement.

The details on the various components of the cost of capital together with the actual calculation of the cost of capital are presented in Table 1.

With the exception of the year 1959 the series for the rate of depreciation is entirely reasonable. As we move into the war period the cost of capital rises because both the rate of depreciation (destruction) and the rate of inflation increase. The general rise in the interest rate is a function of both monetary policies designed to check the rate of inflation and expectations about further price inflation. Nevertheless, this increases the money cost of capital to the government.

The cost of labor is conceptually somewhat simpler than the cost of capital as far as estimation procedures are involved. We define the cost of labor—the cost of military labor—as the average cost per effective military labor unit. We have taken the total U.S. Budget category (Military Pay and Allowances) for the active duty force and divided this by an estimate
Table 1
COST-OF-CAPITAL INDEX

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<tr>
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<td>.034</td>
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<tr>
<td>1956</td>
<td>.108</td>
<td>.028</td>
<td>80</td>
<td>92</td>
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</table>

of effective labor units.\textsuperscript{1} Our focus is entirely on active duty personnel; we have excluded reservists and their associated costs. The measure of effective labor units was derived by weighting the number of personnel in each age cohort (from 17 to 55) by the relative wage of white fully employed males in the same cohort for male military personnel. Female military personnel were weighted by the relative wages of white college and high school graduates for officers and enlisted women, respectively.\textsuperscript{2}

To accurately reflect effective labor units, the year end numbers of personnel engaged in training were subtracted from the total labor force figure. The result was then divided into the total labor cost and the figure expressed in terms of a 1967 base as shown in Table 2. This calculation effectively accounts for training costs. Most training costs are personnel related, and the salaries and allowances of the trainers are the bulk of the costs. By removing these individuals from the denominator we have counted the cost of training.

Figure 2a draws together the calculations of Tables 1 and 2 to present our estimate of the trend in the cost of labor relative to the cost of capital. There are two striking features evident in Figure 2a. First, the series is not a nice, smooth curve. The nature of our cost of capital is such that the continuous process of depreciation is divided into discrete time periods. However, our interest is not in the estimate for any particular year but in the broad trend that may be apparent from the data. Second,

\textsuperscript{1}Our measure of average labor costs does not include retirement costs or medical costs. The true measurement of retirement involves imputing the average discounted present value of retirement benefits (estimated over length of service), assigning portions to service years, and adjusting for the probability of retention. That is, we need to compute the (expected) retirement costs for today's force, not current retirement expenditures. Very rough estimates of these numbers indicate that they are quite small in relation to average labor costs. The same is true of medical costs. The lack of these two items makes our index of labor costs less than all-inclusive; nevertheless, these costs are closely linked to wages, and thus the presentation of average labor costs in index number form would tend to correct for the lack of medical and retirement costs because the proportionality factor would cancel out in both the numerator and the denominator.

\textsuperscript{2}Further details of the calculations and sources of data may be found in Cooper and Roll, (1973) and in a forthcoming paper by the authors.
Table 2
INDEX OF THE AVERAGE COST OF LABOR
(1967=100)

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Index of Average Labor cost</th>
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<tbody>
<tr>
<td>1972</td>
<td>163</td>
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<tr>
<td>1971</td>
<td>140</td>
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<tr>
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<td>70</td>
</tr>
<tr>
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<td>71</td>
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</tbody>
</table>

Source: See text.

and more obvious, is the decline in the ratio during the years 1968 and 1971. As we have noted above, the cost of capital increases considerably during this period, primarily because of the shift in the rate of depreciation during the war. Tables 1 and 2 make it quite clear that costs of both labor and capital are rising over this period, but that the cost of labor did not rise in proportion to the cost of capital. However, if we ignore the heavy war years and concentrate on what may be termed the peacetime trend in costs, the long-term trend in the ratio of the cost of labor to the cost of capital has been increasing. ¹ Such a measure is depicted in

¹A method of examining the hypothesis that the ratio of the cost of labor to the cost of capital has increased over time is to regress the index of relative costs on time and test whether the coefficient on time is significantly greater than zero. The problem with this approach is that the cost of capital shifts up during the war years because the rate of depreciation shifts up. To control for this effect a dummy variable can be inserted in the regression for the war years. The results of the regression are presented below.

\[
CCL = 61.32 - 29.70^* D + 2.82^* T \quad R^2 = .66, \quad n = 17
\]

\((-4.44) \quad (4.86)\)
Figure 2b. The cost of capital underlying the index of relative costs indicated in Figure 2b is calculated using the average peacetime rate of depreciation of about 9.3 percent, instead of the rate of depreciation calculated for each year in Table 1. The upward trend in the cost of labor relative to our estimate of the peacetime cost of capital is unmistakable.

CCL = cost of labor/cost of capital ratio; D = 1 in 1968, 69, 70, 71 and zero otherwise; T = time (1 = 1956, 2 = 1957, ..., 17 = 1972). t statistics in parentheses. * significantly different from zero at 99 percent.

The coefficient on time is significantly greater than zero at the 99 percent level of significance, confirming the hypothesis that the peacetime cost of capital has decreased relative to the cost of labor.
The evidence we have presented above indicates that the current interest in manpower costs is warranted. Despite past concern over the price of capital goods and our finding that capital costs have indeed increased, the price of capital has fallen relative to the price of labor.

What trends are likely in the near future? It is impossible to use historical data and assumptions to project future trends since the abolition of the draft and the move to the all-volunteer force is a large institutional change and produces many uncertainties with respect to the labor supply. It does not seem unreasonable, however, to advance the speculation that the immediate future will see a further increase in the cost of labor relative to the cost of capital. If the cost of capital rises with inflation and there are no large changes in the depreciation rate or interest rate, then the adjustment in terms of the military wages necessary to compete with the civilian sector would almost certainly seem to lead to an increase in the price of labor relative to the price of capital. Once this adjustment process is over we could expect changes in the relative price to match (more or less) those changes occurring in the civilian economy. Thus, we can probably expect to see further relative increases in the cost of labor during the near future before a general leveling off in the relative costs of capital and labor.
IV. IMPLICATIONS FOR RESOURCE MANAGEMENT

We have identified the empirical course of the past (and the immediately expected) upward trend in the cost of labor relative to the cost of capital. The questions to ask, then, become those of adjusting to changes in prices, defining the opportunities for the substitution of capital and labor, and erecting organizational structures for carrying out the substitution possibilities. There are, of course, alternative ways of answering these questions, and we present some of these alternatives below.

ADJUSTING TO CHANGING RELATIVE PRICES

In our previous discussion we presented the changes in input usage in response to changes in relative input prices as if the process were instantaneous. Such an analogy may be valid for very small firms with limited amounts of capital, but it is obviously not correct for such a large institution as the Department of Defense. The manner in which the Department of Defense can respond to a rise in the cost of labor is, in fact, two-fold and may be divided into the short-run and the long-run response.

In the short run, the only variable input is labor. Conditions for efficiency suggest that the amount of labor employed should be reduced in response to a relative increase in the cost of labor. With the capital stock fixed, this seems to imply a lower level of output. However, military capability need not be reduced if the decrease in the amount of labor employed occurs in the maintenance of capital equipment, rather than in the use of the equipment. Of course, the capital would be used up more rapidly, which is one way of substituting capital for labor. At the same time, this increases the cost of capital because it increases the rate of depreciation. Consequently, if one desires to maintain the same level of capability, the process of adjustment to the rising cost of labor entails the raising of the cost of capital. This effect is due to the endogenous nature of the rate of depreciation.

If we consider the long run, the capital stock can be increased through the procurement process. As older elements of the capital stock are retired, the newer elements that replace them can embody more capital and require
less labor. Moreover, new methods of maintenance and operations that employ less labor and more capital can be implemented. Indeed, the principal area that needs exploring is the determination of significant substitution possibilities.

Our initial impression of the capital intensities embodied in the various missions carried out by the Department of Defense is that the weapons systems themselves are relatively capital intensive when viewed from the mission operations standpoint. There may, of course, still be areas where substitution of capital for labor could take place. For instance, the automation of ship propulsion plants seems to be both feasible and cost effective. However, the major possibilities for extensive substitution of capital for labor probably lie in the weapons support area, including both maintenance and logistics. Weapons systems today are highly sophisticated, and the existing practice of repairing and supplying these systems requires vast amounts of manpower. An alternative to repairing these systems is to have a large inventory of spare parts on hand and replace, rather than repair, defective components. Inventories are capital goods, and such a procedure not only would increase the stock of capital but also would reduce the labor force. The reduction would come about in two ways. First since replacement rather than repair is carried out, fewer maintenance personnel would be required. Second, replacement would not entail the skill level required by the ability to repair; the average skill level of the force could be less, and fewer effective labor units would be needed. Similarly, there may be substantial opportunities to substitute capital for labor in the logistical support of weapons systems. For example, base depot operations can be automated. Alternatively, technological innovations, such as precision guided munitions (the so-called "smart bombs"), may require much less manpower for warehousing and supply and are, thus, a form of capital-labor substitution.

Changing the conceptual viewpoint somewhat, divide the force into two components: front-line and support. The front-line forces require certain levels of support. This derived demand should be restructured toward a higher capital intensity. That is, we should look for alternatives to make the support forces more capital intensive. At the same time, alternatives to substitute the more capital-intensive front-line forces for the more labor-intensive support forces should be explored. The construction of equipment with replaceable parts and the subsequent reduction in maintenance requirements is an example of such a substitution.
METHODS FOR ENSURE EFFICIENT RESOURCE ALLOCATION

Military resources are optimally allocated between capital and labor when the technical rate of substitution of capital for labor equals the ratio of the cost of labor to the cost of capital. Moreover, the past and projected increases in the cost of labor relative to the cost of capital suggest that the military should become more capital intensive. The principal questions before us now are:

1. Do current institutional arrangements promote efficient resource management?
2. If not, what alternatives might encourage more efficient resource management?

Before answering these questions, we should first consider what is meant by efficient resource allocation over time, particularly with respect to adjustments to changes in the conditions for efficiency. That is, although equations (3a, b) dictate the conditions for efficient resource allocation between capital and labor, there are both short-run and long-run implications for adjusting to changes in input costs. In the short run, the response to changing costs should encourage substitution of resources rather than a lessening of force capability. In the longer run, we should be especially concerned with the general trends in the relative costs and utilization of inputs. That is, since the costs of labor and capital are partly endogenous, we should direct our attention more to the long-run—and anticipated—trends in these costs rather than just to the yearly changes. For example, we have indicated that the ratio of the cost of labor to the cost of capital is expected to remain significantly higher in the peacetime environment of the 1970s than it was in the peacetime environment of the late 1950s and early 1960s. Will current methods of allocating resources motivate a reallocation of resources toward the more capital-intensive force suggested by this change in costs?

There are, in fact, two reasons why the military would not be expected to respond efficiently to changes in the optimum capital-labor ratio. First, the method of budget submission required by Congress results in an asymmetric treatment of capital and labor services. The budget should be structured in terms of the cost of labor and the cost of capital, but it is actually
structured in terms of the cost of labor and capital procurement costs. This method of budgeting can result in serious misallocations of funds for capital equipment.

Second, the method for determining manpower utilization in the military tends to promote inefficiencies. In each of the Services and in OSD, separate organizational entities are responsible for determining manpower requirements (manpower) and for fulfilling those requirements (personnel). The demand for manpower therefore tends to be constructed independently of personnel costs. Only when individual requirements for manpower and capital are aggregated into total Service budgets is there a general concern for costs. The lack of visibility of costs at the lower planning echelons results in the types of gross adjustments that cut force structure rather than reallocate resources within the given force structure. Methods for avoiding these problems must be developed if DoD is to be expected to allocate resources efficiently. Three possibilities are explored here: (1) centralized military planning; (2) decentralized resource allocation; and, (3) civilian contracting.

The military currently uses a method of centralized planning. However, if this method is to result in efficient resource allocation, then manpower planners must be brought into the early stages of force planning, including both the design of new systems and the use of existing systems. That is, we must move away from the input-output type of manning tables encouraged by the separation of manpower "requirements" and "personnel" and instead recognize in the early planning stages that there are genuine opportunities to substitute capital for labor, or labor for capital, as conditions for efficiency warrant. Second, and equally important, the budget should be restructured to include the cost of capital, not just procurement costs.

An alternative method of allocating resources is to rely on decentralized decisionmaking. Under this option, the manager of each military mission would be responsible for allocating his budget so as to maximize output from that mission. If missions are aggregated such that the marginal contribution of additional capital and labor of any one mission to another is relatively small, then permitting each mission commander to maximize his

\footnote{See footnote 1, p. 11.}
output will result in a maximization of overall defense output and, hence, the optimum allocation of resources. This option then places the major share of responsibility of resource allocation upon the individual mission commander rather than upon a central planning authority.

An alternative way of carrying out decentralization of resource allocation is to contract for certain services in the civilian economy. This may be particularly appropriate for many support functions with direct counterparts in the civilian sector. The military has made good use of this option, even during wartime, but further use may produce greater efficiencies.

**IMPLICATIONS FOR MANPOWER UTILIZATION**

The results of Section II provide a conceptual framework for more efficient utilization of military resources. At the same time, the empirical results presented in Section III make it clear that the cost of labor has risen considerably relative to the cost of capital and that alternatives for a more capital intensive military should be explored. In certain cases it may be desirable to develop equipment with throw-away parts, rather than with repairable parts, thus enabling the military to replace highly skilled technicians with less highly skilled—and less costly—individuals. This would have major implications for the types of individuals acquired by the military and their training. In other instances, it may be worthwhile to replace many less skilled individuals with a few highly skilled individuals. In a more aggregate sense, the occupational mix of the military might be substantially altered by moving to a more capital intensive course. It is clear that these shifts would have major effects on the general training base, as well as on the organizational structure of the military. *Since the direction for change is clear, it is essential that manpower planners take an active role in investigating the possible alternatives for more efficient resource utilization.*
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