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STRATEGIC STOCKPILING AND SUBSTITUTION

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and

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This research report is presented as a competent treatment of the subject, worthy of publication. The United States Air Force Academy vouches for the quality of the research, without necessarily endorsing the opinions and conclusions of the author.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report analyzes the strategic stockpiling methodology used by the Federal Preparedness Agency. A number of limitations of the existing approach are discussed. For example, the basic planning approach does not consider the likelihood of an emergency. This omission is justified only if substitution is not possible. Yet, there is evidence that the economy is capable of a flexible response to an emergency. Thus, an approach is suggested which explicitly accounts for the likelihood of an emergency. Currently the demand for strategic materials is estimated using a model of a peacetime market economy with only a		

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limited allowance made for substitution in production. The estimates of the supply of strategic materials may also be inadequate as the current procedure ignores the use of a price mechanism to activate increases in supply.

A major conclusion is that the variegated nature of strategic materials seems to imply that a more detailed analysis of each material's demand and supply characteristics be accomplished before a stockpile decision is made.

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STRATEGIC STOCKPILING AND SUBSTITUTION

I. Introduction

National mobilization in preparation for emergencies has typically taken the form of stockpiling a variety of goods. For example, military aircraft and pilots are stockpiled because of the lead time required to obtain these assets. Materials such as cobalt, platinum, and chromite are also stockpiled. It has been determined that such materials will be needed in the event of a major land war in order to satisfy both the civilian and military requirements.

The purpose of this analysis is to critique the existing stockpiling methodology. Currently, the Federal Preparedness Agency (FPA) of the General Services Administration uses a complicated model of the economy to help determine the material requirements during a specified emergency. One of the conclusions of our analysis is that it is necessary to focus attention much more carefully on individual materials. One of the problems associated with utilizing a complicated model of the economy is that it is easy to lose sight of the institutional and physical specifics that apply to a certain material. For example, cobalt is a material in which there are significant substitution possibilities in the short run in response to market signals. The model of the economy currently being used does not take these price-induced possibilities into account.

If the costs of stockpiles were not significant, it would be legitimate to hold large amounts of strategic reserves in anticipation of an emergency. However, money capital lays idle when assets are held

in inventory. Investment and consumption opportunities are being foregone to society and the associated costs must be computed using a 10% discount rate.¹ As of June 1976, the value of the strategic stockpile was \$7.6 billion.² This implies that annual costs of over seven hundred million dollars are being incurred. Thus, there must be great care to take a valid approach to the determination of the levels of stockpiles.

This analysis will be presented as follows: First, we will briefly discuss the philosophy which is embodied in the current approach to stockpile planning. Then, there will be a discussion of the economic model now being used. The discussion of this economic model will be followed by an analysis of price-induced substitution, a possibility which is not addressed in the current methodology. We will also illustrate how information relating to price-induced substitution can be used to determine the appropriate stockpile level for the case of cobalt.

II. Planning Philosophy

The FPA computes the strategic stockpile objectives under the assumption that the U.S. will be involved in a major land war of at least three years duration. The objectives are based on an estimate of the difference between the material requirements and the material availability during the first three years of the conflict. The materials stockpiled are assumed to be available not only for military needs but also for civilian sector demands.

In its planning, the FPA makes no assessment of the likelihood of a major land war. It is implicitly assumed that the war will occur

with certainty. Alternative scenarios such as a war of short duration in Europe are excluded from its analysis. This type of "worst-case" planning is valid only if certain conditions are satisfied. For example, it would be valid if there is some likelihood that a long-duration war will occur, and the consequences of not having the stockpiles is national disaster. Then, it is reasonable to plan as if the war will occur, for we should be willing to do what is necessary to protect ourselves against an expected catastrophe. On the other hand, if full technical and end-item substitution is possible, and this substitution prevents the war from being lost, then one must attempt to specify the likelihood of the emergency. This likelihood must be integrated into the economic calculus along with the costs of stockpiling and the costs of substitution when determining the appropriate policy.

This principle can be illustrated in the case of cobalt. Empirical analysis of the short-term demand for cobalt indicates that there are substitution possibilities during the first year of a supply reduction.³ Nickel can perform many of the same functions as cobalt, and when the price of cobalt rises, nickel can be used in its place. Thus, if there is a sudden reduction in the supply of cobalt during an emergency, the absence of cobalt stockpiles will not lead to national disaster because of the substitution possibilities. However, there is a cost associated with this substitution and consideration should, therefore, be given to stockpiling cobalt. But keeping cobalt in inventory also has its costs. As indicated earlier, there is a cost associated with productive resources being idle, and cost-benefit analysis must be used to mediate between the substitution costs and the stockpiling costs. Again, this mediation

must give due consideration to the likelihood that the various kinds of emergencies will occur.

There are metals in which short-run substitutions have not occurred in response to price changes. Chromite has a highly inelastic short-run demand. Therefore, the experience of peacetime suggests that one cannot rely on market induced substitution, and stockpiling of the difference between estimated demand and supply may be an appropriate policy even if there is only a small probability of a long-term land war. An implication of this discussion is that substitution is a key issue in an analysis of stockpiling.

For the remainder of the analysis, we will taken as given the specified international conflict. It should be recognized, though, that the existence of substitution possibilities implies that consideration should also be given to other types of emergencies which might occur.

III. Computation of Strategic Stockpile Objectives

The strategic stockpile objectives are currently based on a demand and supply analysis combined with a three-tier system that is designed to account for differences in risk among the major sectors of the economy. The estimation of the demand for strategic materials during an emergency is made using the Contingency Impact Analysis System (CIAS) and the judgments of material experts about the technical substitution possibilities.⁴ CIAS includes a macroeconomic model of the economy and an input-output model. The supply side estimates are based on the analysis of the material specialists of the Bureau of Mines.

The three tiers which constitute the major sectors of the economy

are the Defense Tier, the Essential Civilian Tier, and the General Civilian Tier. The Defense Tier includes direct expenditures by the defense sector, the Essential Civilian Tier includes civilian expenditures directly related to the war effort, and the General Civilian Tier includes all other expenditures.

An illustration of how the three tier system is employed to account for differences in risk can be made using the supply estimates of the Bureau of Mines. Starting from a baseline equal to these estimates less the supply from war zone and communist bloc countries, the FPA makes adjustments which depend on the tier for which the supplies are to be used. For the Defense Tier, only supplies produced domestically or provided by Canada or Mexico are assumed able to help satisfy demand. For the Essential Civilian Tier and the General Civilian Tier, supplies from an increasing number of countries are assumed available.

To determine the strategic stockpile objective for a particular material, the tiers are evaluated sequentially, the Defense Tier being considered first. If the estimated demand is greater than the allowable supply for this tier, the difference becomes the stockpile objective. One then proceeds successively to the Essential Civilian Tier and the General Civilian Tier computing the stockpile objective for these tiers as the demand shortfall. The sum of the stockpile objective for the three tiers becomes the national stockpile objective for a particular material.

As the estimation of the demand for and supply of the critical materials plays a central role in this procedure, we will discuss in detail these two parts of the stockpiling methodology.

The Estimated Demand for Strategic Materials

The FPA obtains an estimate of the demand for strategic materials using CIAS. The system includes the FPA's macroeconomic model of the economy which is used to forecast the major categories of aggregate demand.⁵ This forecast is made as follows: the CIAS receives as inputs the level of estimated government spending implied by the specified war-time scenario, and, in addition, estimated values of such economic variables as the unemployment rate and the price level during the first year of the international conflict. Given these inputs, the macroeconomic model estimates such components of GNP as Personal Consumption Expenditures and Residential Investment. After civilian austerity requirements are imposed, the Demand Impact Transformation Tables (DITT) are used to distribute the components of aggregate demand to the final demand for each sector of the economy.⁶ These final demands generate indirect requirements on the economy, and an input-output model is used to estimate the total output of each sector. The final link in the CIAS chain is the Material Requirements Model which is a table of material utilization factors which translate the total output of each sector into requirements for critical materials.

Although the use of a macroeconomic model of the economy in conjunction with input-output analysis is an important tool in the long-range forecasting of economic activity, CIAS has a number of limitations when used to forecast the changes in demand which result from a national emergency. These limitations will be illustrated as we discuss each component part of CIAS.

The Macroeconomic Model

As indicated above, the macroeconomic model takes as its input the level of government spending and specified values for such exogenous variables as the price level. The model then estimates such component parts of GNP as Personal Consumption Expenditures and Residential Investment for the specified conflict. Next, the FPA accomplishes a civilian austerity adjustment by varying Personal Consumption Expenditures to follow a prescribed pattern.⁷ For the first year of the conflict, per capita expenditures in this category are increased, if necessary, to 98% of the level achieved the previous year. Then, they are reduced during the next two years to 95% and 93% of the level achieved that year. Thus, if the model forecasts expenditures to be lower than the prescribed pattern, they are adjusted upward. This adjustment violates the notion of scarcity which is embodied in the macroeconomic model and generates an infeasible estimate of the components of GNP. One cannot specify a level of increased government spending, maintain a prescribed pattern for consumer spending and retain a valid estimate of investment spending.

The FPA also makes further adjustments to the demand estimates of the macro model. Spending on consumer durables is reduced and shifted to consumer services and to consumer non-durables. There is a similar expenditure shift away from residential construction into plants and equipment. These adjustment procedures lead one to question the validity of the macroeconomic model and, in fact, the role being played by the macroeconomic model in forecasting demand.

Two additional limitations of the macroeconomic model result from the period of observation it uses and the fact that it lacks a monetary sector. For most of the relationships of the model, the observation period is 1948 to 1976. Thus, World War II, that period most similar to the specified emergency, is excluded. The problem created by not having a monetary sector is that one cannot rely on the money supply to adjust passively during an emergency. Tight monetary policy will probably be initiated in an effort to dampen the inflation associated with increased government spending. One might also expect there to be an extensive administration of credit and the price level during the emergency. The existing macroeconomic model does not capture the impact of such controls.

The Demand Impact Transformation Tables (DITT)

The link between the macroeconomic model and the input-output model is the DITT. The FPA uses these tables to distribute macroeconomic demand to the industrial sectors. For example, the estimated Personal Consumption Expenditures are distributed to such major economic sectors as Household Appliances, and Radio, Television, and Communication Equipment in accordance with historical experience. A problem with this approach is that the peacetime consumption patterns have been used to generate these tables, and it is unlikely that consumers will maintain the same pattern of expenditures during the specified emergency. Thus, there is a definite peacetime bias in the linkage between the macro model and the input-output model.

The Input-Output Model

An input-output model is used to determine the total demand implication of the estimated final demands. For example, the output of the DITT is the final demand of an industrial sector such as Primary Iron and Steel Manufacturing. In order to produce this steel, steel itself is required in addition to the output of the other sectors such as the Petroleum Refinery and Related Industries Sector. The total demand for each sector is determined by adding these indirect demands to the final demands determined by DITT.

Input-output analysis makes the assumption that the input-output coefficients are constant. This means, for example, that each unit of steel produced requires the same number of units of steel, coal, etc., no matter what the demand for steel happens to be. An implication of this assumption is that the substitution of one resource for another in production is precluded. The sort of substitution one might expect during an emergency can be illustrated using the classic guns-butter example. If there is an increase in the demand for guns, the corresponding increase in demand for capital will tend to increase the price of capital, thereby motivating the guns producers to economize on their use of capital. This economization results in a change in the input-output coefficients. Although the preceding argument is abstract, there is empirical support that it applies in the short run when there is a sudden change in demand. During the 1973-74 oil crisis, the changing demand patterns following the reduction in the supply of crude oil led to substitution in production thereby changing the input-output coefficients.⁸

Although input-output analysis is an important tool for forecasting long-run changes in each sectors total demand, when the composition of final demand changes very gradually, its value in estimating total demand is questionable when there is a structural shift in the economy.

The Material Requirements Model

The materials used to produce each sector's total demand are estimated using the Materials Requirement Model. This model is actually a set of coefficients called Material Consumption Ratios (MCR's) which have been developed based on the historical relationship between the output of a sector and the amount of the material used by the sector. As an example, the output of the Aircraft and Parts Sector is used to estimate the demand for titanium by that sector.

The MCR's are adjusted to account for differences among the three tiers of the economy. The Essential Civilian Tier employs the normal projection of the MCR while the Defense Tier uses the upper bound of statistical confidence and the General Civilian Tier the lower bound.

The Materials Requirements Model is subject to the same criticism as the input-output model in that possibilities for substitution in production are ignored. For example, one of the important uses of cobalt is in the production of machine tools. In this use, there is evidence that the amount of cobalt employed depends not only on the quantity of machine tools produced, but also on the price of cobalt.⁹ This price effect which induces both technical and end-item substitution is not considered in the computation of the MCR.

Adjustment for Substitution

The FPA does make some allowance for substitution to the CIAS estimated material requirements based on the judgments of commodity experts.¹⁰ The commodity experts' recommendations are then adjusted depending on the tier to which the material applies and the year of conflict in which the spending occurs. The revisions to the estimated final demands resulting from this procedure are frequently nominal, and the procedure gives no consideration to the actual substitutions which have occurred in response to price movements. For example, although we will see below that there may be market induced substitutions for cobalt, the FPA has made no adjustments to the estimated cobalt requirements.

The bias in the estimates of the substitution potential results from a view of substitution as a purely technological phenomenon. The market-induced substitutions are of a broader type than is predicted by a purely technological analysis. One must add to the substitution possibilities those that result from changes in the consumption of final goods which are induced by material price changes.

Furthermore, the market induced substitutions are a more reliable indicator of what is possible than is obtained from an ad-hoc technological analysis. Much of the decision making associated with the allocation of resources will remain decentralized during an emergency, and what producers have done in the past is the best indicator of what is possible in the future. The question of substitution will be further analyzed below, and we will illustrate the price-induced possibilities for cobalt.

CIAS in Summary

Our discussion indicates that CIAS has a number of limitations. Its macroeconomic model is a model of a peacetime market economy and does not contain a monetary sector. In addition, the output of the model is only superficially used. Personal Consumption Expenditures are maintained, if necessary, at levels which may violate the principle of scarcity. Additional limitations include the fact that the distribution of the component parts of aggregate demand to each sector of the input-output model is based on the peacetime experiences and the fact that both the input-output model and the Materials Requirements Model do not permit the possibility of substitution taking place in production.

These limitations of CIAS cast doubt on the usefulness of the estimated demand for materials. There are also serious problems associated with the supply side of the analysis.

The Estimated Supply of Critical Materials

In analyzing the supply side of the demand and supply equation, we will explore a number of issues which need to be carefully evaluated. Following a review of the existing methodology, we will sum the role played by changes in demand in the Soviet Union and Western Europe on the supplies available to the United States during the emergency. Then, we will analyze the potential role played by price changes in activating increases in supply. Aside from the standard way in which price changes can affect the production of a material, price changes can also play a role in determining that portion of total world production obtained by the U.S. Price changes can also influence the

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quantity of existing stocks supplied by producers and recycling possibilities. The potential role played by price movements highlights both the need to analyze the specific characteristics of a particular material and the need to carefully plan the role which might be assigned to a price mechanism for reducing or eliminating a shortage.

The Current Methodology

The FPA makes a determination of the mineral supply available to the United States during each year of a three year war based on data submitted by the Bureau of Mines. The Bureau of Mines submits to the FPA data on U.S. production and imports of each of the candidate materials. For the first year of the war, data on normal imports are provided, whereas for the remaining two years the data are adjusted based on the assumption that production is at capacity level and a certain percent of the material shipped is lost in transit from enemy activities.¹¹ The FPA deducts from the import data those shipments coming from the war zone and the Communist Bloc countries. Then, as indicated above, the supplies are further adjusted depending on the tier in which the supplies are to be used. We will discuss a number of limitations of the supply figures utilized by the FPA.

Western Europe and Soviet Demand

Although the U.S. may receive a substantial level of imports from the Soviet Union and Western Europe in normal times, these supply sources are not included in the net supply estimates used by the FPA. This adjustment may be inadequate. The demand for materials in the Soviet Union and Western Europe will also be affected by a major

land war, and this change in demand will influence the level of supplies which are available to the U.S. For example, if West Germany were to be involved in a land war, then its demand for chromite would be affected. Similarly, the Soviet demand for mercury would increase. In order to build additional bomb primers the Soviets would attempt to capture a larger portion of the world supply of mercury thereby impinging on the share currently received by the U.S. These examples illustrate the need to analyze carefully not only the role played by those countries directly involved in the conflict as suppliers but also as demanders of those materials needed in the U.S.

The Role Played by Price Changes

The supply of strategic and critical materials could be significantly altered by price changes. The following questions need to be answered for each material: If the price increases, will domestic production of the material increase? If the U.S. pays a higher price for a certain material, will a larger percent of world production be supplied? If the price of a material rises, will recycling become more important? Currently, these questions are not being investigated in the determination of supply estimates. To emphasize their importance, each is discussed in detail.

Price and Domestic Production

If the price of a particular mineral increases sufficiently, increases in domestic production might be possible in the short run. For example, if the price of cobalt were to increase from \$4.40 to \$5.50 per lb., domestic production would probably be initiated.¹² There is a

high grade source of cobalt in Idaho which was operational prior to 1971. Recently, however, the market price has been low and there has been no domestic production.

Although the cost of building a new mine or regenerating a "mothballed" mine might be prohibitive, each specific material must be carefully analyzed to determine whether increased domestic production during the first, second, or third year of an emergency is possible.

Price and World Supply

Embodied in the current methodology is the assumption that relevant world production will continue at a normal level during the first year of the emergency. This production level is assumed to be independent of price and the U.S. imports are derived under the assumption that the U.S. will retain the same share of relevant world production. Although it might be reasonable to assume that the world supply schedule is independent of price in the short run, it is questionable to assume that the supply schedule faced by the U.S. is also perfectly inelastic. If the U.S. demand for a particular material increases, say as a result of the emergency, the higher price the U.S. would be willing to pay could result in the U.S. obtaining a larger portion of the world supply. The U.S. can, in effect, bid the material away from other users. Thus, the U.S. supply schedule can be price elastic at the same time as the world supply schedule is perfectly inelastic.

One method of gaining some insight into the increased supply possibilities is by determining that part of relevant world production which is being consumed by the U.S. This determination is meaningful, because, other things equal, the smaller the percent of world production

being consumed in the U.S., the greater the ease in increasing consumption via a price rise. Table I provides estimates of this percent for several materials.

TABLE I

U.S. IMPORTS AND ESTIMATED WORLD PRODUCTION (1973)¹³
(WESTERN EUROPE AND SOVIET UNION EXCLUDED)

	<u>U.S. Imports</u>	<u>Estimated World Production</u>	<u>U.S. Pro- portion of World Production</u>
Alumina (thousand short tons)	5,719	16,710	.341
Chromite (thousand short tons)	300	1,820	.165
Cobalt (thousand pounds)	12,075	35,590	.340
Platinum (thousand troy ounces)	304	765	.398

In constructing this table, we assume that the reduction in U.S. imports and the reduction in world production resulting from supply nonavailability in Western Europe and Communist Bloc countries is the same proportion to total U.S. imports and total world production respectively. Thus, the U.S. is only consuming approximately 16.5% of the relevant world chromite production during the first year of the emergency, and approximately 39.8% of the platinum. By paying a higher price, the U.S. should be able to obtain a greater percent of the total.

Price and Commercial Stocks

Substantial private industrial stocks of raw materials do exist. They are maintained for important reasons: protection against commercial or transportation interruption and speculative stocking in anticipation

of future price increases. Table II illustrates how large some commercial stocks were in 1972.

TABLE II
U.S. CONSUMPTION (1972) AND PRIVATE INDUSTRIAL STOCKS
(12/31/72)¹⁴

	<u>U.S. Consumption</u>	<u>Private Industrial Stocks</u>	<u>Stocks as Proportion of Consumption</u>
Alumina (thousand short tons)	6,968	1,079	.15
Chromite (thousand short tons)	1,140	857	.75
Manganese Ores (thousand short tons)	2,331	1,795	.77
Platinum (thousand troy ounces)	543	392	.72

We can see that the commercial stocks of chromite, platinum, and manganese ore were significant enough to alleviate possible short-term supply disruptions. In fact, the commercial stocks of these materials were equal to approximately nine months of 1972 consumption.

For other materials, the commercial stocks are not significant. Alumina is an important example. Nevertheless, each material should be analyzed individually with respect to private stocks when determining the government's strategic stockpile objective. It is necessary to analyze the specific role played by a commercial stockpile and the incentive for private producers to reduce their stocks during an emergency.

Price and Recycling

Secondary production, called recycling, is very important for certain materials. Examples of materials where there is extensive recycling are platinum and cobalt. The high price of platinum makes it economical for almost all platinum products to be recycled. Recycling is also very profitable for cobalt. Each year about one million dollars of scrap material containing cobalt is exported to Japan, Taiwan, West Germany, and Belgium for recycling. These scraps could be recycled to remove and reuse the cobalt in them.

Many materials are not currently recycled. Manganese recycling only occurs as a fringe benefit when iron and steel scrap are recycled. A large price increase, however, would be necessary to induce an increased amount of manganese recycling.

For each material, it is necessary to determine the recycling supply potential as a function of price. This information could be used to further assess the role played by the price mechanism in determining the supply of critical materials during an emergency.

Limitations of the Existing Supply Methodology

We have seen that the methodology used to compute the supply of strategic materials has a number of limitations. The existing approach fails to consider changes in demand in Western Europe and the Soviet Union and fails to account for the role played by the price mechanism. The variegated character of strategic materials seems to require a detailed analysis of each material's availability.

On the demand side, there are also characteristics of materials which make it appropriate to treat each individual material separately. We now discuss the possibility of price-induced substitution.

IV. Substitution in Production

During peacetime, the U.S. normally relies on markets and market signals to allocate resources. This allocation process includes a myriad of substitutions in both consumption and production which are responses to price signals. Within this environment, producers have responded to market signals, and this response has generated data which permits a determination of many of the substitution possibilities.

In wartime situations, there are classic examples of dramatic substitutions taking place in non-market economies such as those occurring in Germany during World War II and more recently in North Vietnam.¹⁵ These substitutions were accomplished using direct administration of resources. During emergency situations, the U.S. would likely use a combination of existing markets and direct administration to achieve the appropriate allocation of resources and the necessary resource substitutions. This discussion suggests that one must view strategic stockpiling as being, in essence, a question of the substitution possibilities during emergency situations, and the degree to which stockpiles can alleviate the costs associated with the adjustment process.

Although there are possibilities available for substitution, the fact that the substitutions are necessary implies that a less than "preferred" production method must be used. It is these costs which can be alleviated with stockpiling. Stockpiling, however, has its costs which also must be considered. It is costly for money capital to be tied up in stocks and these costs must be balanced off against the costs of substitution. The primary indicator of the short-run substitution possibilities is the price elasticity of demand. The price elasticity

of demand is defined as the percentage change in demand associated with a one percent increase in the price of the material. Table III contains estimates of the price elasticities and specifies certain principle substitutes for several significant materials.

TABLE III
PRICE ELASTICITIES OF DEMAND¹⁶

<u>Material</u>	<u>Short Run</u> ¹	<u>Long Run</u> ²	<u>Principle Substitutes</u>
Aluminum-Bauxite	-.13	-0.80	copper, steel, wood, plastics, titanium
Chromite	0 to -0.2	elastic	nickel, molybdenum, vanadium
Cobalt	-0.68	-1.71	nickel
Copper	-0.3	elastic	aluminum, plastics
Lead	inelastic	elastic	rubber, copper, plastics, tile, titanium, zinc
Mercury	inelastic	-1.0	
Molybdenum	inelastic	N.A.	tungsten, vanadium
Platinum-Palladium	0 to -.1	-.4 to -.9	gold
Tungsten	-0.15	-0.3	molybdenum
Zinc	-.55	-.67	aluminum plastics

¹One year

²Three to five years

Although these elasticities were estimated using peacetime data, the changes in demand which apply during the emergency will not necessarily change these significantly. Much of the demand for strategic materials is from

the private sector, and it is not clear that the price elasticities associated with the private sector will change significantly during wartime. Thus, it seems reasonable to use the short-run demand elasticities when analyzing the substitution possibilities during the first and perhaps the second year of the emergency. During the third year of the emergency, the long run price elasticity could be used. From Table III, cobalt is a material in which price induced substitution is possible. It and nickel are somewhat interchangeable in production, and experience indicates that a one percent rise in the price of cobalt results in a .68 percent reduction in its consumption. On the other hand, chromite is an example of a material which has an almost perfectly inelastic demand in the short run. However, the absence of price induced substitution does not necessarily indicate that one is willing to pay any price for the material. The elasticities in Table III are based on historical experience, but there may not have been sufficient price variation to capture the short-run substitution possibilities.

Thus, it is possible to employ demand elasticities to obtain insight into the question of which materials can be rationed with the aid of the price mechanism and which materials might require direct government administration. We will not discuss how the estimates of short-run price elasticity of demand can assist in the computation of the optimal level of strategic stockpiles.

An Illustration of Stockpile Computation

An approach to the computation of the optimal stockpile will be illustrated for cobalt for the first year of the emergency. This material was selected because short-run price elasticity of -0.68

indicates that there is a possibility for price-induced substitution. To simplify the presentation, we do not distinguish among the spending tiers in which the cobalt is to be used and assume that the excess demand for cobalt during the first year of the emergency is 28,000 thousand pounds.¹⁷ We do not take into account the possibility of price-induced substitution when the excess demand is computed.

We have discussed the need to explicitly consider the probability that an emergency will occur whenever substitution is possible. Therefore, we determine the optimal stockpile as a function of the likelihood of an emergency. In our computations, a price of \$3.00 per pound is used. This price is between the low price of \$2.45 and high price of \$3.30 which applied during 1973.

To illustrate the procedure, we assume that the stockpile is used in support of the first year of the conflict exactly one year after the stocks are obtained. A detailed discussion of the methodology is presented in the Appendix. However, insight can be achieved into the rationale behind the approach by recognizing that the last unit of cobalt purchased for the stockpile costs \$3.00 now. In view of the fact that the Office of Management and Budget has specified a discount rate of 10%,¹⁸ there must be expected benefits of \$3.30 in one year in order to justify holding money capital in a cobalt stockpile. These expected benefits are a weighted averaged of the price which would be generated by the stockpile release and the \$3.00 for which the unit of cobalt could be sold if the emergency were not to occur. The weights used to compute this average are the specified probabilities. After determining the appropriate price following the stockpile release, it is possible to

determine the level of stockpiles which would just generate that price. That level would then be the stockpile objective. The relationship between the stockpile objective and the likelihood of an emergency is presented in Figure 1.

OPTIMAL COBALT STOCKPILE AS A FUNCTION
OF LIKELIHOOD OF EMERGENCY

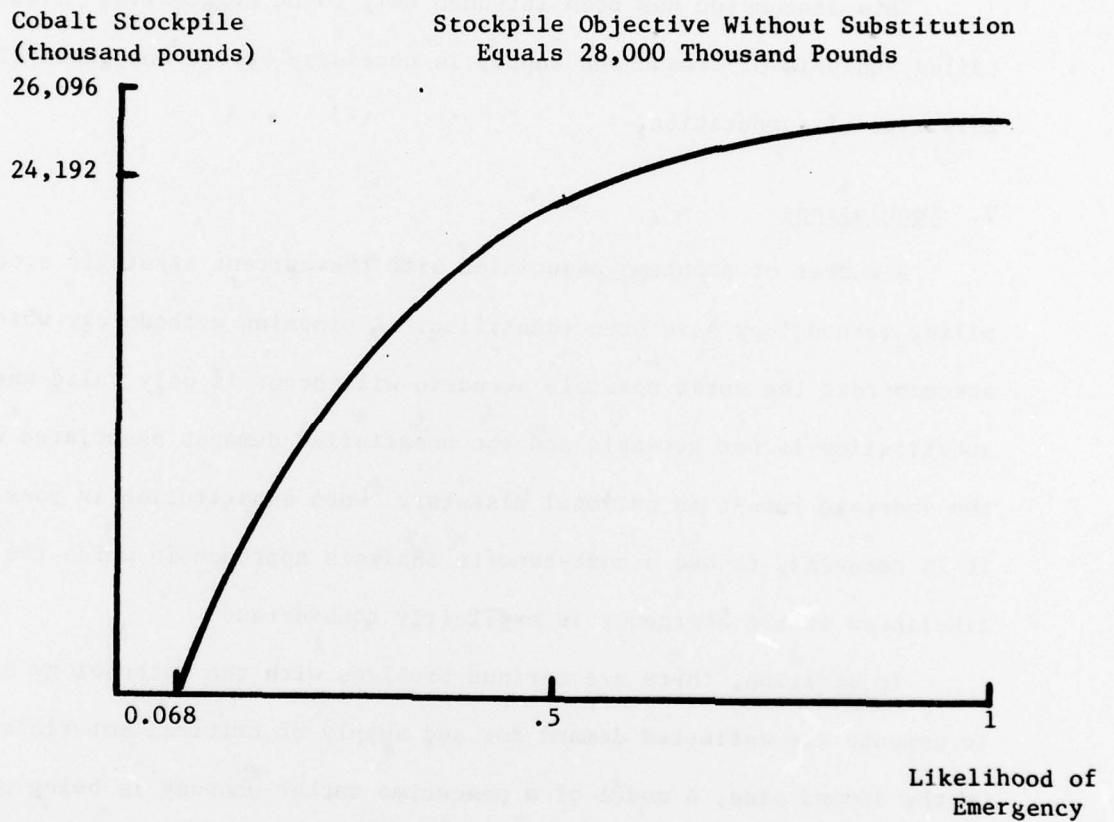


Figure 1

The nonlinear relationship indicates that the likelihood of an emergency increases the appropriate stockpile in size less than proportionally. For there to be any cobalt stockpile at all, it is necessary that the likelihood of an emergency be at least .068. On the other hand, if the emergency were to occur with certainty, then it would be appropriate to keep in inventory 26,096 thousand pounds of cobalt.

This discussion has been intended only to be suggestive. A detailed analysis of demand and supply is necessary before one accomplishes this type of computation.

V. Conclusions

A number of problems associated with the current strategic stockpiling methodology have been identified. A planning methodology which assumes that the worst possible scenario will occur is only valid when substitution is not possible and the unsatisfied demands associated with the shortage result in national disaster. When substitution is possible, it is necessary to use a cost-benefit analysis approach in which the likelihood of the emergency is explicitly considered.

In addition, there are serious problems with the methodology used to compute the estimated demand for and supply of critical materials. On the demand side, a model of a peacetime market economy is being used to forecast demand during an emergency. The requirement that Personal Consumption Expenditures be maintained at a specified level raises questions about the feasibility of achieving the estimated composition of aggregate demand. An additional limitation of CIAS is that an input-output model may not be the appropriate tool to forecast total

demand by sector. Input-output analysis assumes that no substitution in production will occur and there is evidence that such an assumption is not valid.

On the supply side, there is no consideration given to the potential role played by variations in price. These variations might activate an increase in supply. The sources of the increased supply include increased U.S. production, the U.S. gaining a larger share of world production, the release of private industrial stocks, and increased recycling. Furthermore, the computation does not give any consideration to the possible change in consumption in Western Europe and the Soviet Union during the conflict and the effect of this change in the supply available to the U.S.

Some evidence has been presented that price-induced substitution is possible. A suggested methodology for computing the appropriate level of stockpiles for alternative likelihoods of the emergency is included.

VI. Recommendations

The current approach should be modified so that the specific characteristics of each candidate material are more effectively incorporated in the analysis. A determination should be made of the substitutions that are possible in the marketplace. A thorough analysis of the planning methodology utilized seems necessary not only for an analysis of stockpiling, but of all defense related programs.

Footnotes

- ¹This discount rate is to be applied to all government expenditure projects. See OMB Circular No. A-97, March 27, 1972.
- ²GSA News Release #6681, Attachment 2, October 1, 1976.
- ³The specifics of the short-run substitutions for cobalt will be discussed below.
- ⁴For a discussion of CIAS, see "The MCL-Thurrow Model-Supplement," pp. 12-16, by Patricia R. Divine, GSA/OP/MCL TR-96, February 1975.
- ⁵See "The MCL-Thurrow Model," by Patricia R. Divine, GSA/OP/MCL TR-93, February 1974.
- ⁶DITT and the remaining parts of CIAS are documented in "DITT Data Estimates and Input-Output Review," February 1972, IST-103, Assistant Director of Resource Analysis, Office of Emergency Preparedness.
- ⁷The civilian austerity assumption is discussed in "A Study of the Effect of Lead-Time, Substitution and Civilian Austerity in the Determination of Stockpile Objectives," July 15, 1975, General Services Administration, Federal Preparedness Agency.
- ⁸These changes in input-output coefficients have been analyzed by Randall G. Holcombe in "The Economic Impact of an Interruption in United States Petroleum Imports: 1975-2000," November 1974, Center for Naval Analysis, CRC 245.
- ⁹See Charles River Associates report "Cartilization in the World Cobalt Market: Economic Analysis and Policy Implications," p. A.6a, February 1976.
- ¹⁰For a discussion of the FPA substitution philosophy, see "A Study of the Effect of Lead-Times, Substitution, and Civilian Austerity in the Determination of Stockpile Objectives."
- ¹¹Interview with Dr. John Morgan, Jr., Acting Director of the Bureau of Mines, United States Department of the Interior, Washington, D.C., July 1976.
- ¹²Interview with Mr. Scott F. Sibley, Bureau of Mines, United States Department of the Interior, Washington, D.C., July 1976.
- ¹³The data contained in Minerals in the U.S. Economy: Ten Year Supply-Demand Profile for Mineral and Fuel Commodities (1965-74), Bureau of Mines, United States Department of the Interior was adjusted as follows: Using chromite as an example, the U.S. imports

during 1973 were 393 thousand short tons of which 93 thousand short tons came from the Soviet Union. World production during the year was 2,386 thousand short tons. The assumption is made that U.S. total imports of chromite is the same proportions of total world production as U.S. imports from U.S.S.R. is of U.S.S.R. total production. This assumption implies that the U.S.S.R. production of chromite during 1973 was approximately 566 thousand short tons. Deducting this amount from the world production of 2,386 thousand short tons yields an estimated world production, net of U.S.S.R. production, equal to 1,820 thousand short tons.

- 14 U.S. Bureau of Mines, Minerals Yearbook, 1972, Vol. I is source of data for Table II.
- 15 A discussion of these substitutions is contained in "On War and the Principle of Substitution" by Colonel Herman L. Gilster, Directorate of International Economic Affairs, Office of the Assistant Secretary of Defense, International Security Affairs.
- 16 These price elasticities have been estimated by Charles River Associates, Incorporated of Cambridge, Mass., and are summarized in "Testimony of Dr. James E. Burroughs Before the Subcommittee on Economic Growth of the Joint Economic Committee of the Congress of the United States, Washington, D.C., 10:00 a.m., July 22, 1974," a report published by Charles River Associates.
- 17 The stockpile objective for cobalt is currently 85,415 thousand pounds for the three year conflict (GSA News Release #6681, Attachment 2, October 1, 1976). To illustrate our methodology we use an excess demand number which is approximately one third this amount.
- 18 See footnote 1.

APPENDIX

We will let P_1 be the market price of cobalt generated by the stockpile release during the first year of the emergency and q will be the probability that the emergency will occur. Then, the discussion on page 22 indicates that the stockpile should be used to generate a price P_1 which satisfies

$$\frac{qP_1 + (1-q)3}{1.10} = 3 .$$

This relationship can also be expressed as

$$P_1 = \frac{3(.1 + q)}{q} . \quad (1)$$

Given a P_1 and the price elasticity of demand, it is possible to determine the appropriate stockpile, for it is simply that level which yields a price P_1 during the first year of the emergency. We will assume in the stockpile computation that the demand for cobalt is approximately linear within the relevant data range. An initial demand for cobalt of 28,000 thousand pounds and a pre-emergency price P_0 of \$3.00 per unit then implies that each dollar increase in the price of cobalt reduces demand by approximately 6,347 thousand pounds. This is because

$$-.68 = \frac{\Delta D}{\Delta P} \frac{P_0}{D} = \frac{\Delta D}{\Delta P} \frac{3}{28,000}$$

or $\Delta D = -6,347\Delta P$

where $\Delta P = P_1 - P_0$

ΔD = Change in demand.

In that the change in price ΔP equals $P_1 - 3$ and the stockpile

requirement S equals 28,000 less the reduced demand, we can solve for the relationship between the emergency price and the stockpile level:

$$P_1 = \frac{S-47,041}{-6,347} .$$

Then, substituting the right hand side of this relationship for the emergency price P_1 in Equation (1), and rearranging terms, we obtain the following relationship between the stockpile level and the likelihood of an emergency:

$$S = 28,000 - \frac{1,904}{q} .$$

It is this relationship which is graphed in Figure 1.