Chapter V

POSSIBLE IMPACTS OF ECONOMIC STOCKPILING

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The impact analysis encompasses both economic and noneconomic considerations. Under the latter category, the political, social, and market-operations impacts which might result from implementing an economic stockpile are considered. It should be emphasized, however, that because the economic factors associated with an economic stockpile are far more important than the non-economic factors, the analysis concentrates on economic impacts. Two distinct techniques were used to examine the economic impacts: the University of Maryland's INFORUM model, and the Economic Welfare Model developed in the assessment.

For purposes of this assessment, economic impacts have been separated into two types; first, the benefits and costs which accrue to the United States, either directly or indirectly, as a result of the impact which stockpiling has on the domestic economic welfare; and second, the direct, out-of-pocket costs to the stockpile investor for operating the stockpile, costs which include the acquisition and disposal of materials.

The term impacts defines changes in the circumstances of individuals, groups, or nations which occur as the result of implementing a particular stockpile policy. Impacts may occur as a result of the activity associated with building a stockpile, as a result of operating it, or as a result of dispersing from it. Impacts may be real (changes in employment levels) or perceived (fear that an economic stockpile would be used to reduce the power of a strike); local (environmental effects of mining marginal ores) or global (creation of new trading alliances); social (improvement in the choice of products or range of lifestyles available); political (frustration of cartel action); or economic (stabilization of prices). In short, impacts encompass a vast range of consequences which maybe of significance to the United States and its citizens.

The impact analysis here is organized into two basic categories: (1) first, the general impacts considered applicable to all five stockpiling policies (the political, social, and market operations impacts); (2) the impacts specifically applicable to each of the five stockpiling policies (the economic impacts), Accordingly, the following sections are included in chapter V:

- General impacts of economic stockpiling;
- SP–1: Economic impacts of stockpiling to discourage or counteract cartel or unilateral political actions affecting price or supply;
- SP–2: Economic impacts of stockpiling to cushion the impacts of nonpolitical import disruptions;
- SP–3: Economic impacts of stockpiling to assist ing international materials market stabilization;
- SP-4: Economic impacts of stockpiling to conserve scarce domestic materials; and
- SP–5: Economic impacts of stockpiling to provide a market for temporary surpluses and ease temporary shortages,

A. GENERAL IMPACTS OF ECONOMIC STOCKPILING

The general impacts which may result from implementing any form of an economic stockpile can be considered in three areas: political, social, and market operations, Each of these general impact areas will be discussed in this section, followed by an analysis of the economic impacts which may result from implementing stockpile policies (SP) 1–5.

1. Political Impacts of Economic Stockpiling

Building a stockpile to guard against supply interruptions or to help stabilize prices can have important political significance. Both exporting and importing nations can be affected. Internally, many organizations will be politically involved in supporting or opposing the creation of stockpiles.

a. Effects on International Relations, Trade Alliances, and Agreements.—Economic stockpiling will influence international relations, creating an environment for new alliances and new means of demonstrating support and solidarity among nations. Even when an economic stockpile is designed primarily for domestic reasons, it will have international implications. There are at least three ways international relations might be affected:

(1) Exporting nations might call on allies to support their action to raise prices or divert or withhold supplies from the United States;

(2) The creation of an economic stockpile within the United States might deter the formation of cartels in other materials or affect aspirations of other potential consortia members; and

(3) An economic stockpile could reduce the risk of serious confrontation between the United States and materials controlling nations.

The International Energy Agency (IEA) is an example of a defensive stockpile formed among importing nations with a common need for a material controlled by a cartel. The program of IEA is designed to allocate supplies to member nations and to reduce competitive bidding for scarce supplies of petroleum. The program is enacted when there is a general supply emergency or when an embargo is aimed selectively at one or more of the member nations. Shortages are shared among the nations when they exceed 7 percent of previous consumption. Less severe shortages are managed by conservation. Rules for using stockpiles enable countries to share the risk of supply shortfalls. These rules avoid the "self-targeting" problem which arises when only one member, e.g., the United States, has and releases large stockpiles. Thus, under the IEA the United States does not become a "prime target" for an embargo because it possesses stockpiles.[1]

The size of an economic stockpile like SP-1, which is designed to withstand a politically inspired embargo, might well be based on the contribution which the material makes to the economy of the exporting nation. For example, an exporting nation which relies heavily on revenues derived from the export of a particular material could itself survive only a relatively short interruption; therefore, a stockpile designed to guard against this interruption could be small. However, third-party nations, allied with the exporting nation, could change this balance by offering the exporting nation loans, subsidies, or alternate markets,

A stockpiling policy like SP–3, which is aimed toward regularizing the international flow of materials, might be viewed as defensive (guarding against the eventuality of high prices) or offensive (forcing prices down when market conditions would dictate otherwise). Thus, the political impacts of SP–3 depend on how the policy is conceived, perceived, and implemented. As in the case of SP–1, this policy could well result in consuming nations' forming joint stockpiling arrangements other than the IEA so that the collective risk to any member is sharply reduced. To the degree that such an effort is successful in stabilizing markets, long-range policies based on the interests of both producing and importing nations may well be easier to arrange. For many commodities, the existence of a stockpile would be a modest guarantee of stability, both of the international market, and through this leverage, the capital flow to the producers. Thus, if a stockpile is not seen as a threat which induces immediate, negative reaction from producer nations, it may well enhance the possibility for cooperation among nations with common interests in stabilizing material flows.

lsee Federal Energy Administration, Project Independence Report (Washington, D. C., U.S. Government Printing Office, 1974), pp. 369-377.

The creation of an economic stockpile within the United States might also deter the formation of cartels in the material being stockpiled or in other materials. The increasing dependence of the United States on imported materials, discussed in chapter II, suggests that by the year 2000 imports may account for more than 90 percent of all chromium, tin, titanium, platinum, beryllium, aluminum, and fluorine which the U.S. consumes. In this situation, supply interruptions may become increasingly common, To the extent that stockpiles of important materials exist, potential cartels will see them as a deterrent, an obstacle which would have to be overcome before their actions could be effective. Hence, the formation of cartels and/or the effectiveness of their actions could be constrained by the creation of a U.S. stockpile.

An economic stockpile could also reduce the risk of serious confrontation between the United States and materials-controlling nations during an embargo or a trade action. If, during an embargo, serious economic dislocations occurred in the United States due to scarce supplies, the pressure to give up previous foreign policy objectives or to take aggressive action could be substantial. The tension created by possible confrontation of world powers could thereby be increased. The difficulty of the situation is compounded by the need for quick a&ion. If there were no stockpile, or if only a token amount of material existed in the stockpile, the acquisition of additional material could become an issue in itself. If an essential ingredient in diplomacy is time, then the existence of the stockpile may be politically valuable insofar as it helps provide that time.

On the other hand, the creation of an economic stockpile might bring about counterproductive results. It could, for example, be viewed as a threat by foreign producer countries, triggering the imposition of embargoes or adverse pricing policies. Indeed, stockpiling may be perceived by exporting nations as an implicit act of aggression, since it suggests distrust of those foreign nations who control needed U.S. materials. While the timing of stockpile implementation may provide the leverage to weaken a cartel at a moment when the relations between the members are strained, it could likewise coalesce the cartel and elicit threatening responses in terms of price escalations.

The involvement of third-party nations in a manner which could be adverse to U.S. interests is also a possibility, particularly in the case of SP–1. In general two possibilities appear plausible: (1) third-party nations might intervene by supporting exporting nations through direct subsidies, grants, favorable trade arrangements, or the provision of new markets; or (2) other importing nations could become involved by entering into agreements with the United States to form a cooperative effort for emergency sharing of reserves.

The success of the Organization of Petroleum Exporting Countries (OPEC) has been instructive to other producer groups and may affect the formation of other materials cartels. Jamaica, for example, recently took the step of raising the bauxite ore tax by 700 percent, despite its exceptionally vulnerable economic position. Jamaica has an adverse (and worsening) balance of trade, and could benefit from foreign-aid program assistance provided by nations such as the United States. However, Jamaica was convinced that its interests were better served by actions which in no sense appeased or accommodated the United States or other consumer nations. An important, perhaps crucial, factor in such situations may be the willingness of OPEC nations to abet other nations in these desires, z The existence of a stockpile within the United States could have an effect on such activities and could probably affect the creation and operation of consortia in materials being stockpiled, The stockpile would set the minimum level of embargo which a consortium would have to impose to be effective, If the exporters' economies were not strong enough to endure the embargo period implied by the stockpile size, the stockpile would clearly be a deterrent to the formation or operation of a new consortium.

b. Effects on U.S. Domestic Politics.—Economic stockpiling designed to keep the economy strong will probably be welcomed by labor and business in general, because both benefit from high levels of economic activity. However, business or labor directly involved in primary materials production or consumption are more strongly connected to materials supply and price and therefore may have specific, short-term interests which may conflict with each other or with the broader business or labor community. In general, a stockpile may be seen by labor as a means of maintaining jobs in the presence of a supply interruption. In general, a stockpile may be seen by business as a means of stabilizing international price fluctuations. However, labor, business, and other groups will be concerned over the eventual or potential use of the stockpile, regardless of its announced purpose. For labor in the materials production sector, the possibility exists that a stockpile could blunt the threat of strikes. For business in the materials production sector, a stockpile could represent an intervention into the marketplace and the possibility of governmental action adverse to its interest. For these reasons, some sectors of labor and the business community are likely to be wary of the Government's efforts to build and operate an economic stockpile. The interviews conducted in this assessment certainly corroborate such a watchful point of view, and were used as inputs to this impact analysis.

To the extent that the operation of an economic stockpile tends to stabilize cyclic market performance, opposition may be anticipated from producers and consumers who see cyclic market performance contrary to their interests, whereas support may be anticipated from those who find cyclic performance useful. The intended purpose of a stockpile like SP–5, for example, is to insure that materials flows are adequate. This means that the price of the stocked commodity will not be

[2] *Wall Street Journal*, Aug. 13, 1975, p. 9.

influenced by “panic” buying or hoarding when supplies appear short. As price and supply fluctuate, so do employment, loading of transportation resources, capital investment in new plants and facilities, and consumer product prices.

Raw material consumption and prices are cyclic, closely following general economic trends, The cycle is evidenced more significantly in some extractive and production industries than others, in which increasing demand can lead to the construction of new capacity which, when available, provides excessive capacity. Prices then fall and new capacity additions become infrequent. When these facilities are taxed because of rising demand, prices again rise and the cycle reestablishes itself,

Public attitudes with respect to a stockpile like SP–5 could be expected to vary, depending on the phase of the stockpile cycle involved. In general, a stockpile used to alleviate shortages in materials which are produced domestically may be resisted by domestic producers, who could expect to benefit from such shortages. But the stockpile would also, through purchases during periods of oversupply, protect domestic producers from the effects of declining prices. Producers would presumably favor such protection, considered by itself, while consumers would worry about subsidized production resulting in artificially high price levels. The stockpile could be used to prevent unhealthy surges to nonmaintainable price levels during periods of shortage and declines in production during periods of surplus, thereby protecting both consumers and producers in the long run. Nevertheless, many producers and consumers would fear that inadequate information, administrative lethargy and inefficiency, and political pressures would all combine to make an economic stockpile less attractive. On principle, some would also object to the paternalistic and controlled-market aspects of the stockpile.

To implement SP–5, data on materials supply and demand would probably be required from industry in even greater detail than might be required for some of the other four stockpiling policies analyzed. Industry may object to the Government’s gathering of such data. A comprehensive stockpiling system could be politically sensitive in this way and could generate strong opposition,

On the other hand, U.S. Government purchases of scarce raw materials (SP-4) could stimulate resource development by minimizing the unsettling effects of temporary declines in discovery rates or variations in prices. Sales from the stockpile at the stabilized higher price might protect domestic industry from the eroding effects of price fluctuations of foreign imports. The stockpile would provide a constant market which could encourage capital formation to support domestic extraction industries and insure minimum and continuing production levels, The assured high price level could encourage the development of new technology, both to enhance production of scarce domestic materials through mining or processing breakthroughs and to provide lower cost and more plentiful substitute materials. It could also be a strategy for preserving within the United States a minimal amount of technical expertise concerning the extraction and production of such scarce materials. For all of these reasons, a stockpile like SP-4 might be favorably received by the relevant producing industries, However, unless a clear, overriding national need were demonstrated for such favored governmental treatment, individual consumers and consuming industries could be expected to object strongly to this market interference which, conceivably, could restrict supply and raise prices.

2. Social Impacts of Economic Stockpiling

Social impacts are difficult to analyze because they are diffuse and vague. These impacts can affect the individual (e.g., mobility and leisure) or society as a whole (perceptions about the world role of the United States); they can relate to institutional or regulatory changes (rationing or allocation programs); or they can bring about social changes of world scope (new patterns of migration and changing social aspirations of other nations),

It is assumed that the United States would remain a consuming society, heavily dependent on the use of resources to achieve what most of its citizens now consider to be a desirable standard of living. This premise naturally leads to policies which help assure uninterrupted flows of materials. Stockpiling may be seen, for example, as an instrument not only for maintaining economic stability, but for encouraging such desirable actions as energy conservation and the development of new material technologies. Yet, the situation leading to the need for an economic stockpile, and the discussions surrounding the implementation and use of such a stockpile, may ultimately contribute to a much more profound impact than any considered explicitly here—i.e., a change in values and expectations with respect to consumption in the United States and around the world.

It is also important to note that some social impacts vary with each phase of stockpiling operation. For example, if petroleum were diverted from imports in significant quantities to help provide a stockpile inventory, mobility could be adversely affected; however if a stockpile were already in place, it could help assure mobility in the presence of an embargo. Social impacts, in particular, have a quality of requiring adverse current or near-term impacts in order to reduce risk or uncertainty in the future.

Of the five stockpiling policies considered, SP–1 could have the most important social impacts. This is true for four reasons:

- The need for, and effort to build, a stockpile is apt to gain national attention, and thus stimulate debate because the quantity of material required for this stockpile policy could be massive;
- The amount of material which would have to be diverted into the stockpile could affect consumption patterns and may require establishing new laws and regulations to allocate or ration materials;
- The stockpiling action itself could change national and international perceptions about the role of the United States on the world scene; and
- The stockpile may be seen either as a valuable concrete action in an otherwise frustrating world situation, or as an attempt to preserve an inefficient lifestyle.

In particular, SP–1 demonstrates the need to weigh potential short-term adverse effects during the stockpile acquisition period against the potential long-term beneficial effects after acquisition has been completed, Acquisition of sufficient stocks to discourage or counteract politically motivated supply interruptions may require temporary domestic allocation or rationing and thereby result in diminished mobility and restricted patterns of leisure activity. However, such acquisition is intended precisely to avoid adverse consequences in the long-term future. Used in anticipation of a unilateral political action or cartel, this policy would divert imported materials or domestically produced materials into a stockpile. The effect of this diversion during the acquisition period could be to raise prices of products utilizing the material and perhaps to limit the availability of the material in some applications. But assurance of the future availability of essential resources could result in stabilized supplies of fabricated goods, so that anticipation of the security offered by the stockpile may be accepted as the justification for diverting material from current consumption. Moreover, as discussed above, the adverse impacts incurred during the acquisition stage can be mitigated or even eliminated by implementing a gradual, rather than a one-shot, acquisition program or by filling the stockpile needs from nonmarket sources, such as existing excess stocks in the strategic stockpile or in defense reserves.

Since the stockpile required by SP–1 would have to be quite large to have a deterrent effect, its operation would probably result in appreciable public discussion and possibly economic dislocations, The question which would naturally follow would be: "Why are consumption and dependency on foreign supplies so high?" Discussions about desirability of growth, utilization of economically marginal domestic supplies, and manipulation of our destiny by foreign powers would be stimulated, The response to such discussions is difficult to forecast and depends on other factors which exist at the time, including in particular the stance of the media, economic conditions, as well as domestic and international political stability.

a. Effects on Prices and Consumer Choice of Products.—The range of choice of products available to the public could be affected as a result of price changes and the differential effect of these changes on various socioeconomic groups. During the creation of a stockpile, the flow of material into the market could be restricted, and its price would probably rise. If this occurred, the price of certain products would also increase, making it more difficult for people in lower socioeconomic levels to purchase the more expensive products. During the disposal phase of the stockpile, however, the effect could be reversed. Of course, it is possible to introduce compensatory legislation which would minimize the regressive effects of stockpiling acquisition.

The major social impact of SP–5, for example, would be to reduce the regressive effects of price changes in society. As pointed out earlier, when prices rise, certain sectors of society are least able to afford more expensive goods and services; therefore, as prices rise, there is a regressive effect on lower socioeconomic groups. This stockpiling policy would help minimize that effect. Furthermore, consumers in general would have a more stable supply of goods, both from the standpoints of price and availability.

However, as mentioned previously in the discussion of political impacts, inadequate information, lethargic or inefficient administration, and political pressure may result in the stockpile's exacerbating problems rather than solving them. Price-support actions during periods of surplus might result in artificially high prices being maintained over the long-run, Conversely, sales from the stockpile during periods of shortage might be excessive and damage the productive capacity and competitive posture of the producing industry. The potential for intentional or unintentional misuse of a stockpile for SP–5 seems appreciable.

Furthermore, if the stockpile were large enough, diversion of materials into the stockpile could cause temporary shortages and price changes. Such a diversion could have direct adverse impacts on the consumption and personal lifestyles of U.S. citizens for the duration of the acquisition program. However, the temporary adverse impacts potentially attributable to stockpile acquisition could be mitigated or even eliminated by a planned, phased program of acquisition which purposely avoids a large immediate impact on the market. Furthermore, for at least some of the materials considered for stockpiling, nonmarket sources for acquiring materials exist, although it may be desirable to open these sources to the market rather than funneling them directly to a stockpile.

In the case of oil, for example, one plan calls for using the Elk Hills Naval Petroleum Reserve for stockpile purposes.[3] Elk Hills is estimated to contain close to 1 billion barrels of reserves, which can be produced at the rate of approximately 400,000 barrels per day, Similarly, the zinc required for an economic stockpile could be obtained from the 171,955 short tons currently held in excess of the stated objective of the strategic stockpile administered by the General Services Administration (GSA).[4]

[3]Senate Report 327, 94th Cong., 1st sess. 2–4 (1975). Naval Petroleum Reserve No. 4 in Alaska is estimated to contain 10 to 33 billion barrels of oil, but unlike Elk Hills the capability for immediate production does not exist in NPR 4.

[4]Inventory of Stockpile Material as of Oct. 31, 1975, Office of Stockpile Disposal, GSA.

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b. Effects on Perceptions of United States in World Affairs.--One subtle social impact of SP–3, which concerns international materials market stabilization, would be to promote changes in perceptions about the abilities and role of the United States on the world scene. This policy would likely be part of an international commodity agreement; however, in some instances, it could be implemented as a unilateral stockpile. Ideally, it would involve both producing and consuming countries, and the stockpile would serve as a buffer stock to be built when prices are low and supply is high and utilized in the reverse circumstances. The exact nature of this impact will depend on many external factors which exist at the time, including in particular foreign nations' perceptions of the intent of the stockpile. Within the United States, if the stockpile is seen as a responsible and effective means of exerting control over national policy, it could help promote political cohesiveness.

3. Market Operations Impacts

Economic stockpiling entails acquisition and disposal of materials in excess of normal demand and supply at the time of purchase and sales. At the very least, an economic stockpile overhangs the market as a force in being which cannot but affect market behavior. Insofar as its object is to prevent or counteract supply interruptions, the stockpile alters the risks and rewards of normal market actors. Insofar as its object is to alter terms between buyers and sellers, it constitutes direct, purposeful intervention to change the consequences of normal market operations to bring about results more compatible with the policy objectives.

Stockpiling operations are likely to be invoked in circumstances of shortage or threat of shortage, surplus or threat of surplus, or wide price fluctuations. These are the very circumstances in which the normal actors in the marketplace are most likely to be big gainers or big losers. This inherent ability of the stockpile to affect winnings and losings not only alters the patterns of private risk decisions (to invest, produce, buy, sell, inventory, etc.); it makes the stockpile administration the object of extreme pressures from private risk-takers to influence the buy/sell decisions. Stockpiling may also have an adverse effect on investment, insofar as the overhanging stocks threaten to truncate the upper end of the price range and thereby add arbitrary, nonmarket risks to investment.

Discouraging investment is one consequence of the unpredictability of market behavior which, in the presence of relatively large stocks subject to administrative control, can result in "excessive accumulation in the first instance and subsequent massive dismantling in the second, disrupting the minerals economy in both phases. "[5] Of course, what is "excessive" or "massive" depends on the purposes to be served and the quantities to be bought, sold, or held to achieve them. What is suitable as the amount of material to be stockpiled may be "excessive" to those who are dealing commercially in the market for materials. Indeed, such stockpile amounts, which are themselves often a matter of dispute within the Government, may change with circumstances (or administrations), leaving the market to cope with run-up or liquidation of stocks, which may be sudden by market standards.[6] The American Mining Congress contends that an economic stockpile should be surrounded by strict safeguards to avoid effects which will "obstruct the natural function of a free market. "[7]

The markets for stockpiled materials are generally worldwide. For many, the demand fluctuates cyclically, as do the corresponding price fluctuations. Market intervention in the form of stockpiling might either moderate or exaggerate the market behavior, depending on the purpose, the timing, and the management of the stockpile, In any case, the overhanging stockpile could depress the price level

[5] *American Mining* Congress journal, "A- Declaration of Policy, 1974-1975" (Oct. 6, 1974), p. 7.

[6] See Case Study, "Release of Copper from the Stockpile" Appendix B.

[7] American Mining Congress.

throughout the market cycle even where that was not its intent.

These market impacts obviously affect the distribution of risks and rewards between producers and consumers, both intra- and international. The impacts on less-developed countries can be particularly felt. In many cases, such countries have seen themselves as exploited suppliers of raw materials at low prices and importers of high-priced manufactured goods.[8] They perceive the periods of high prices as their only opportunities for equitable treatment, and in this view, a U.S. economic stockpile would appear as a threat which would diminish their market power in periods of heavy demand or interruptions in supply. But in many countries and materials, time and events have overtaken this view: the growing demands and diminishing supplies of certain minerals are changing the terms of trade and have led to demands from less-developed countries for a more positive role in the decisions governing supply and price. The United States is now having to reckon with these changing relationships.[9]

The growth of world demand, coupled with the spectacular success of OPEC, has encouraged the less-developed countries to demand both higher prices for their exports and protection against continued inflation of the prices for their imports. While it has traditionally resisted these demands, the United States appears to be moderating somewhat in the direction of accommodation with the positions of the less-developed countries.[10]

The economically weak suppliers of mineral raw materials in the past have pressed for international "stabilization" agreements which would have the effect of regulating supply and setting floor and ceiling prices. As a principal importer, the United States has been reluctant to enter into such agreements, professing a preference for competitive markets and in any case resisting output restrictions which it regards as too high, However, the United States has recently signed the Fifth International Tin Agreement (ITA) which is now before the U.S. Senate awaiting consent and ratification. The ITA is the only operational international commodity agreement for a metal.

Many of the materials which are candidates for stockpiling are actively traded in nationwide or worldwide markets which mediate between producers and users. Stockpiling, as an explicit mode of government intervention in the market for public purposes, can markedly affect market and price behavior by upsetting the expectations of buyers and sellers.[11] Sometimes, in cases where markets are sensitive and prices volatile, these effects can be quite out of proportion to the quantities acquired or sold,

When current or forward market prices are built into production or pricing decisions of suppliers or users of important materials, as may be the case with aluminum or copper, market intervention may have a destabilizing effect. One such effect may be felt if the result of the stockpiling is to activate high-cost domestic suppliers who may find themselves unable to compete commercially when the stockpiling objective is achieved. This can happen in the commercial market also, of course, but it is then the result of market forces and market risks, not necessarily public policy decisions. These actions add to uncertainties and may upset competitive relationships, perhaps even the locus of production and employment.

On the other hand, successfully executed stockpiling operations in support of public ob-

[8] This view was formulated systematically by Raoul Prebisch in a series of papers issued by the U.N. Economic Commission for Latin America, and is currently being voiced at the UNCTAD IV discussions in Nairobi.

[9] See, for instance, the speeches of the U.S. Secretary of State to the Kansas City international Relations Council, May 18, 1975, and to the U.N. General Assembly, Sept. 1, 1975.

[10] See *New* York Times (Aug. 27, 1975), p. 1.

[11] For example, the decision of the International Monetary Fund to dispose of so million ounces (about $7.5 billion) of the gold from its "stockpile" drove down not only the price of gold but sympathetically the price of silver. New York Times, Sept. 3, 1975, p. 49.

jectives could, if pursued steadfastly and consistently over time, reduce uncertainty by bounding risks and the consequent market behavior. In this respect, stockpiling might have an effect analogous to that of the currency support operations of central banks in a system of floating exchange rates, by putting all parties on notice that the permissible range of fluctuations would be limited by government action. A comparatively small stockpile of raw sugar, for example, might have moderated the runaway sugar market in the latter part of 1974. Once suppliers, users, and intermediaries become convinced and accustomed to the stockpiling operations, such operations could reduce the risks on all sides and permit production and consumption decisions on the basis of efficiency within those bounds.

Under these conditions, the operators of the stockpile undertake the burden of performing the functions of the market in allocating scarce resources, many of which are becoming scarcer and more costly, as well as differentiating between market manipulation and real changes in the supply prices for the quantities demanded. This is far more difficult than short-term supply or price stabilization. Because public policy objectives may be incompatible with economic efficiency, public management may have adverse and difficult-to-forecast economic effects on the allocation and use of resources. The history of regulation of natural gas is perhaps an inexact but nevertheless useful analogy. These incompatibilities can generate both economic and political impacts: the economic impacts arising from the changes in the burden of risks/rewards and the distortion of the normal market incentive effects on supply/demand; the political impacts of interests, regions; and nations trying to influence management decisions to their advantage.

SP-4, for example, could have a significant impact on the evolution of domestic industry since it would, in effect, establish a "floor" price for various materials in short supply. Known economic objectives for development of substitute materials would be set. In addition, as cost levels change, the economic incentive to develop indigenous marginal resources and substitute materials could also change.

A U.S. economic stockpile could provide a floor price for a particular material as a means of stimulating industries which are now economically "submarginal" but which have a potential for becoming stable industries in the near future. Furthermore, providing a floor price would encourage investment in research to develop substitute materials, since the federally backed price would provide an economic goal for the new technological development. Within the social domain, the consequences of shaping technology in this way include reducing dependency on imports, losing other technological opportunities as a result of diversion of manpower and skills, changing future product mix and costs, stimulating opportunities for spinoff technologies, and creating technologies which may be well suited for export.

In achieving these policy objectives, SP–4 could also affect the domestic environment. Extractive industries would be encouraged to develop marginal resources so that the materials extracted could be used at a later date. Planning for this policy must therefore include careful consideration of such environmental factors as land use (including questions relating to the use of Federal lands), availability of water, and land restoration and runoff.

The impacts of an economic stockpile on market operations can be summarized in four major points:

(1) The operation of an economic stockpile is an intervention into the market and as such it could obstruct the natural functioning of the market. This interference could pose certain elements of risk to consumers, producers, and stockpile investors;

(2) If the stockpiling objectives were pursued in a constant and consistent fashion, the market uncertainty and risk

created could be bounded, most likely within acceptable levels;

(3) Some of the possible problems which may occur could be short-run and transitory in nature and do not appear to be significant impediments to policy implementation; and

(4) There may well arise possible conflicts between economic efficiency and policy objectives due to political objectives in a spacific stockpiling situation. This could be a crucial issue in ultimate acceptance of stockpiling as a policy alternative.

B. ECONOMIC IMPACTS OF STOCKPILING TO DISCOURAGE OR COUNTERACT CARTEL OR UNILATERAL POLITICAL ACTIONS AFFECTING PRICE OR SUPPLY (SP-1)

The Economic Welfare Model as presented in chapter IV is a method for assessing, in specifically estimated dollar amounts, the possible economic impacts of a stockpile to discourage or counteract cartels or unilateral political actions affecting price or supply. The derivation of the Economic Welfare Model for SP-1 is logically divided into two steps: (1) creating a decision tree to identify the spectrum of events which can possibly occur, and (2) developing the cost and benefit functions related to the policy objectives in order to estimate the probable economic net benefits.

The decision tree for SP–1 is shown in figure V–1, As in game theory, the tree identifies the possible damages, costs, and damages averted (consequences) as a result of cartel events occurring when a stockpile does not exist, or when a stockpile does exist, The probability associated with each event is noted on the branches of the tree.

The cost function used to estimate the possible costs of implementing SP–1 is explained in chapter IV; the benefit function used to estimate the possible benefits of SP–1 is explained immediately below. In evaluating the benefit function, one should note the difference between the possibility (certainty) and the probability of an event's occurring, The Economic Welfare Model, used to estimate when and how much of a material should be included in a particular stockpile, is based on the probability that some event affecting the normal flow or price of a material will occur. For example, approximately 28 percent of the zinc presently used in the United States is imported from Canada (55 percent of the total U.S. zinc imports), thus there is the possibility that 28 percent of the zinc requirement could be disrupted by an event which cuts off this supply. However, the probability of such an event happening is very small. Therefore, to stockpile a quantity of zinc metal equal to 28 percent of the U.S. requirement assumes that the event would happen with a probability of 1. That is unrealistic and would lead to a stockpile far in excess of real requirements.

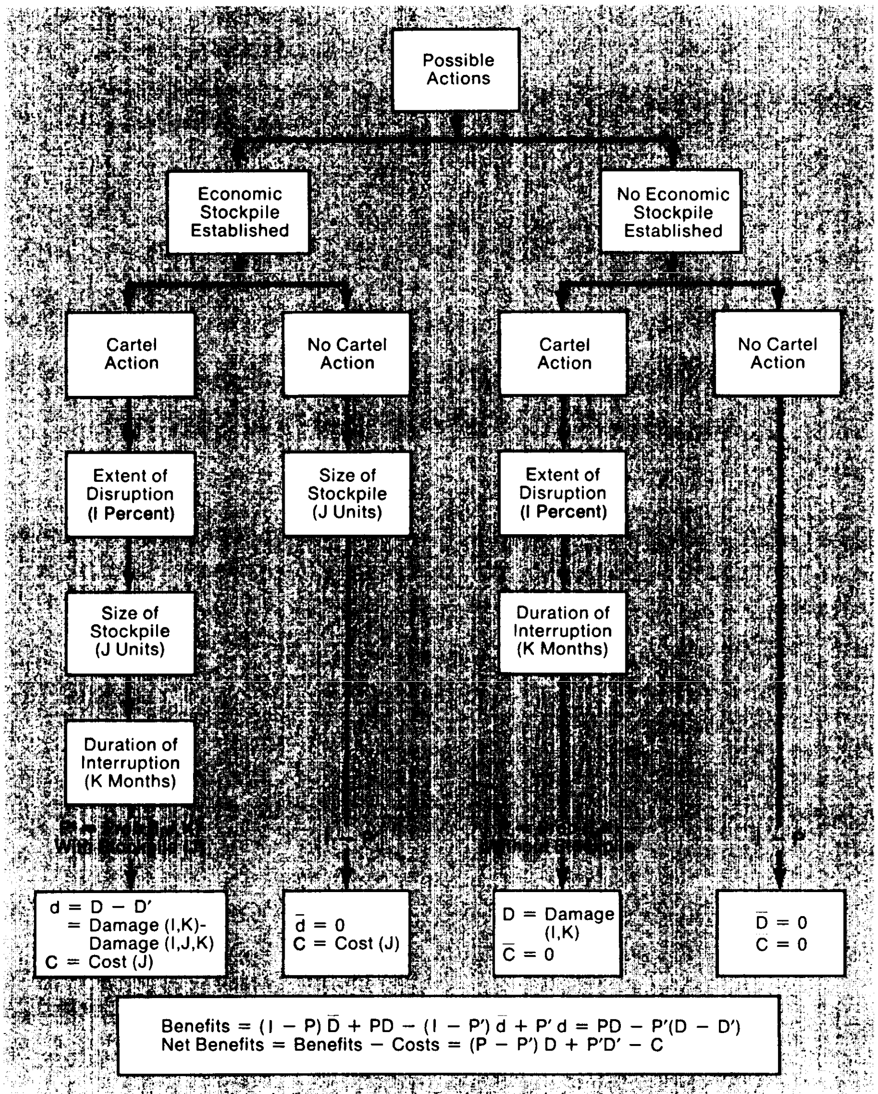
1. Derivation of Benefit Function for SP–1

The decision tree for SP–1 indicates that a stockpile for SP–1 will have two inherent benefits:

- Those derived from the aversion of a cartel or unilateral political action, and
- Those derived from the counteraction of such action after it has occurred.

The benefits derived over the coming time period depend on whether a cartel or unilateral action artificially restricts supply or raises prices, If either event occurs, the benefits are equal to the potential damage to

Figure V-1.
Decision Tree for SP-1



the United States which the stockpile prevents. If neither action occurs because the existence of the stockpile discouraged them, the benefits are equal to the damage averted. Since it is impossible beforehand to know whether such an action will or will not occur, the optimal level of stocks should be determined on the basis of the expected benefits. For a stockpile of a given size, these benefits are equal to: (1) the damage which the stockpile could counteract, multiplied by the probability that a cartel or unilateral action will occur even though the stockpile is in existence; plus (2) the damage which the stockpile averts through discouragement of a cartel or unilateral action, multiplied by the probability that the action would occur without a stockpile.

The damage and probability products are multiplied by 1 plus a risk aversion factor (l+r) which reflects society's reluctance to be exposed to damaging events. The risk aversion factor is analogous to an insurance policy covering a highly damaging (costly) event which has a very low likelihood of occurring. The risk aversion factor is relevant principally when the economic net benefits are negative or the damage not averted by the stockpile is large (presumably due to low probabilities)—enabling the stockpile managers to consider whether a value for r exceeding zero would be appropriate for the specific policy and material being considered. That is, if the event could be sufficiently disastrous (regardless of the probability of its occurrence) that expenditures above those economically justified would be reasonably committed, some positive value assigned to r would increase the expected benefits to the point that economic benefits become positive. That is,

(9a)

where

B = benefits
r = risk aversion factor
D = damage of the action without stockpiling
D' = damage counteracted with the stockpile
P = probability of the action without stockpiling
P' = probability of the action when a stockpile exists

Equation (9a) implicitly assumes that only one type of action by a cartel or unilateral action can occur. Of course, this is rarely, if ever, the case. Conceivably, such actions can embargo anywhere from zero to 100 percent of imports. They can raise prices so high that all imports cease or so little that the domestic demand for imports is negligibly affected. They can last a few weeks or several years. In order to consider the range of possibilities as depicted in the decision tree, equation (9a) can be modified as shown in equation (9b).

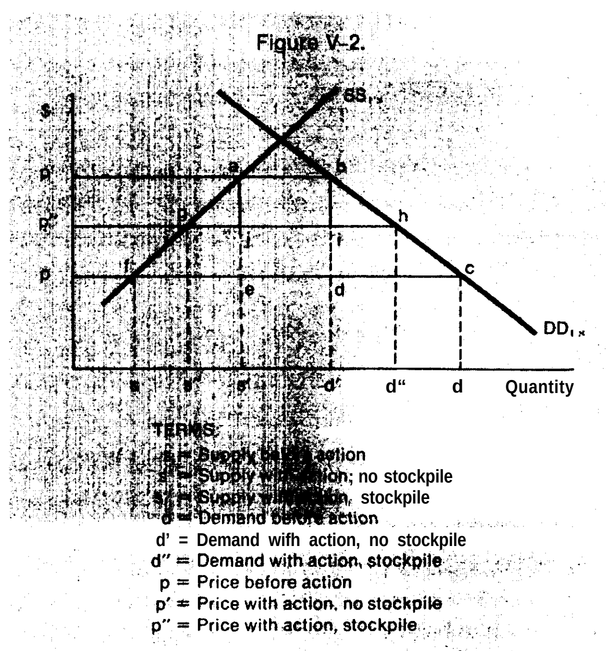
$$B = (1+r)\sum_{i} \sum [D_{ik}(P_{ik}-P'_{ik}) + D'_{ik}P'_{ik}] \quad (9b)$$

where

i = the categories representing extent of import disruption
k = the categories representing duration of the disruption in months

The expected benefits of a stockpile are equal to the probability that imports will be restricted in the time period considered (due either to an embargo or the imposition of higher prices) multiplied by the damage this would cause, both with and without the stockpile. The import disruptions considered must encompass the entire spectrum of possible import disruption with regards to both percent and duration of interruption. The probability that any cartel or unilateral action will occur must be less than or equal to one. Therefore, the probabilities of possible interruptions can be developed to encompass the entire spectrum of events.

The damage incurred by the United States in the event of a cartel or unilateral action which restricts imports by 50 to 75 percent, for example, depends in part on the net loss of consumer surplus caused by the rise in price. Figure V–Z (below) illustrates this loss by the trapezoid abcf on the assumption that the cartel or unilateral action in the absence of a stockpile would raise the price to domestic consumers from p to p'. Again, it is important



to point out that the actual loss to domestic consumers is p'bcp, an amount which could appreciably exceed abcf. The difference, however, goes to domestic producers as a transfer payment and does not represent a loss of real resources to the country.

If the stockpile is large enough to discourage a cartel or unilateral action, then the damage averted (D) includes all of trapezoid abcf, If a cartel or unilateral action occurs even though a stockpile exists, then the damage which can be counteracted depends upon the size of the stockpile. If the stockpile were large enough to keep the price of the material in question from rising above p, the damage counteracted would include all of the trapezoid abcf. If this were not the case and the stockpile could only keep the price from rising from p', the savings in consumer surplus would be indicated by the trapezoid abhg.

Since damages expressed in the benefit function are expected damages (i.e., dependent on the specified probability of an import interruption), the optimal stockpile size is unlikely to avert all damages. In figure V–2 above, the stockpile is sufficient only to reduce the price to p". Hence, the damage which the stockpile is not able to avert is the trapezoid ghcf. Consequently, estimation of damage not averted is important if policy makers are to intelligently address the tradeoff between higher stockpile costs and the damage not averted.

The probability (P_{ijk}) that an action will Occur with a stockpile in existence is dependent upon the size of the stockpile. Likewise, the damage (D_{ijk}) counteracted is also dependent upon stockpile size as reflected in the price reduction (p") achieved by release of stocks, The benefits (B) of a stockpile of size (Q_i) are given by thefollowing equation:

$$B_i = (1+r)\sum_k \sum [D_{ik}(P_{ik}-P'_{ijk}) + D'_{ijk}\ P_{ijk}] \quad (9c)$$

where j = identifier of a stockpile of size Q_j

As pointed out in chapter IV in the discussion of the cost function, a price rise may impose, in addition to the net loss in domestic consumer surplus, external costs on society which are not borne by the consumers of the material. For as the latter cut back their production, their suppliers may be hurt and their employees laid off. There may be external costs of a different nature as well. For example, cartel and unilateral actions of the type considered here tend to aggravate international relations between the United States and other countries. The benefits which a stockpile produces by avoiding or reducing these external costs should be counted in the benefit function.

The damage (D_{ik}) a stockpile discourages for a cartel or unilateral action of i percent, k month is estimated from the following equation, so that:

$$D_{ik} = CS_{ik} - PL_{ik} + ED_{ik} \quad (lo)$$

where

- D_{ik}= damage without stockpile
- CS = consumer surplus without stockpile
- PL = producer loss without stockpile
- ED = external damage without stockpile

From figure V–2:

$$CS = d'(p'-p) + 1/2(d-d')(p'-p) \quad (11a)$$

$$PL = s'(p'-p) - 1/2(s'-s)(p'-p) \quad (11b)$$

which gives the damage function of:

$$D_{ik} = 1/2(s_{ik}-s)(p_{ik}-p) + 1/2(d-d_{ik})(p_{ik}-p) + (d_{ik}-s_{ik})(p_{ik}-p) + ED_{ik}) \quad (11c)$$

where

- s = supply without an action
- P = price without an action
- d = demand without an action

The total damage to the United States is equivalent to the counteracted damage (Dijk) of a stockpile of sufficient size (Q_j) which completely offsets the cartel or unilateral action—i.e., a quantity large enough to lower the price (p") so that it equals the price (p) prior to the cartel or unilateral action.

Once all of the components of equations (10) and (11) are estimated, the damage averted can be calculated. The expected economic benefit of a stockpile of size (Q_j) can be calculated from equation (llc), given society's aversion to risk (r) and the probabilities (P_{ik} and P_{ijk}) associated with cartel or unilateral actions. It should be noted that the probabilities of a cartel or unilateral action effecting a given reduction in imports are likely to decrease as the size of the stockpile increases, since the larger the quantity the smaller and more distant are the benefits of such an action to exporting countries. To trace out the entire benefit function, the calculations described above should be repeated for stockpiles of various sizes,

The foregoing discussion implies that the damage(D'_{ijk}) a stockpile could counteract, should a cartel or unilateral action cut imports by i percent fork months, can be estimated by:

$$D'_{ijk} = CS'_{ijk} - PL'_{ijk} + ED'_{ijk} + CG_{ijk} \quad (12)$$

where D', CS', PL', and ED' are defined in equation (10) and CG_{ijk} capital gains (losses) accrued by disposal of the stockpile.

From Figure V–2:

$$CS' = d'(p'-p'') + 1/2(d''-d')(p'-p'') \quad (13a)$$
$$PL' = s'(P'-p'') - 1/2(s'-s'')(p'-p'') \quad (rib)$$

which give the damage function of:

$$D'_{ijk} = 1/2(s_{ik}-s_{ijk})(p_{ik}-p_{ijk}) + 1/2(d_{ijk}-d_{ik})(p_{ik}-p_{ijk}) + (d_{ik}-s_{ik})(p_{ik}-p_{ijk}) + ED'_{ijk} + CG_{ijk} \quad (13c)$$

where

S_{ik} = supply when the action occurs without stockpiling

s_{ijk} = producer supply with disposal of the stockpile j

p_{ik} = price when the action occurs without stockpiling

p_{ijk} = price with disposal of the stockpile j

d_{ik} = demand when the action occurs without stockpiling

d_{ijk} = demand with disposal of the stockpile j

The first term on the right-hand side of equation (13c) estimates the savings in consumer surplus which arise because domestic producers incur a smaller increase in real incremental costs due to the fact that their output increases only to s" rather than s'. As figure V–2 illustrates, this savings (which is reflected by the triangle ajg) is equal to one-half the increase in domestic supply, which did not occur due to stockpile releases, multiplied by the increase in price, assuming the domestic supply curve is approximately linear in the price range p" to p'.

The second term in equation (13c) estimates the savings in consumer surplus which occurs because fewer consumers of the material are driven out of the market. This savings is reflected in figure V–2 by the triangle bhi. Equation (13c) assumes that the demand curve over the relevant price range is linear so that this component of consumer surplus can be estimated by one-half of the product of the prevented increase in domestic price and decrease in domestic demand.

The third term of equation (13c) represents the savings in consumer surplus which arise because the price paid to foreign producers is kept at p", rather than being permitted to rise to p', This savings is reflected in figure V-2 by the rectangle abij. It can be estimated by the product of the prevented price increase and the level of imports which would occur at the price p',

The fourth term (ED') reflects the savings produced by the stockpile in the external damages which are not borne by the users of the material. The first three terms can be approximated on the basis of estimates of the prevented price increase (p'–p") and the elasticities of domestic supply and demand which apply for the time period and price range being considered. It is far more difficult to estimate ED'.

The fifth term, capital gains or losses (CG), related to disposal of a portion or all of the stockpile are determined from the difference between the acquisition and disposal prices. These gains (or losses) are added to the damages averted for counteraction of a specific interruption as given in equation (12). Capital gains (losses) were explicitly computed for stockpiling policies 3, 4, and 5 in order to illustrate its application and test the sensitivity of this variable. Capital gains ('losses) were set at zero for policies 1 and 2.

2. Types of Economic Impacts Associated With SP-1

Four types of economic impacts resulting from stockpiling under SP–1 can be estimated using the Economic Welfare Model:

- Direct benefits and costs to materials producers,
- Direct benefits and costs to materials consumers,
- Benefits and costs borne by the stockpile investor, and
- External benefits and costs resulting from stockpile operation.

These benefits and costs occur in each of the three phases of the operation of an economic stockpile, Estimates of each of the four types of economic impacts have been made and are presented following this discussion.

a. Materials Producers Incur Direct Gains or Losses in Domestic Producers Surplus.—Materials producers are impacted during all three phases of the operation of an economic stockpile under SP–1. During acquisition, the materials producers derive a gain from the increased demand for a commodity and the resulting higher prices. The holding phase of stockpile operation does not generate actual losses for materials producers; however, during this phase the existence of the stockpile will prevent producers from reaping gains as a result of a cartel or unilateral action. That is, the producers will not be able to sell the commodity at increased prices and obtain excess profits.

The direct benefits and costs to materials producers can be estimated by the gain or loss in domestic producer surplus. During stockpile acquisition, the direct producer gain (PG) is dependent upon the rate of commodity accumulation and the resultant price impact of the accumulation. The direct producer loss (PL) during the disposal stage can be determined from the damage function and the probabilities that an event will occur.

b. Materials Consumers Incur Direct Gains or Losses in Domestic Consumer Surplus.—Materials consumers are impacted concurrently with materials producers under SP–1. When the materials producers incur a direct gain, the materials consumers incur a direct loss, and vice versa. The difference between the direct consumer loss and the direct producer gain is the net loss (savings) in domestic consumer surplus, During the acquisition phase of an economic stockpile under SP–1, the materials consumers suffer a direct loss due to the increased price of the stockpiled commodity. The materials consumers realize a direct savings or gain in the holding and disposal stages as a result of discouraging or counteracting cartel or unilateral actions,

The direct benefits and costs to materials consumers can be estimated by the savings or loss of domestic consumer surplus. As with direct benefits and costs to the materials producer, the direct impact on materials consumers is the expected loss or savings.

c. Direct Benefits and Costs Are Borne by the Government In Operating the Economic Stockpile.—These costs are the initialization costs during the acquisition phase, the holding costs, and the disposal costs, The direct benefits of the stockpile operation are the capital gains (or losses which give negative benefits) realized upon disposal of the material in the stockpile. Under SP–1, capital gains or losses can only be realized if the stockpile is used to counteract a cartel or unilateral action when it occurs. Therefore, the benefit is the expected capital gain or loss, which is the possible capital gain or loss multiplied by the probability that a cartel or unilateral action will occur,

d. External Benefits and Costs are the Indirect Economic Costs and Benefits of the Stockpile.—These externalities are included in the cost and benefit functions of the

Economic Welfare Model. The external costs of acquisition and the external costs averted through holding materials to discourage cartel or unilateral actions and of disposing materials to counteract such actions are a major portion of the economic net benefits of an economic stockpile,

These externalities, which are caused by stockpile operation and cartel or unilateral actions, arise from the indirect effects of price changes or supply interruptions, These indirect costs are not easily attributable to either materials producers or consumers, but apply generally to the producers, the consumers (both immediate, intermediate, and final), as well as to other parties,

3. Estimation of Economic Net Benefits for SP-1

Calculations are presented for a key material in order to demonstrate the use of the Economic Welfare Model as a means of estimating, on a macroeconomic scale, the economic net benefits to the United States of economic stockpiling. For the input variables specified, the calculated values were produced by computer program.

Petroleum has been selected as the example material to demonstrate how the Economic Welfare Model can be used to determine when and how much petroleum should be stockpiled to achieve the two objectives of SP–1. The calculations related to this example demonstrate that the quantity of a material to be stockpiled should properly be based upon the probability of a supply interruption, rather than on the possibility of such interruption.

a. Background Information.—The values and assumptions for the key parameters used in the estimations are summarized below.

- Postembargo U.S. demand for petroleum remains constant at 6,010 million barrels per year, of which 2,000 million is met by imports,
- U.S. domestic supply remains constant at 4,010 million barrels,
- There is a price response to changes in the supply which varies with the intensity and duration of import interruption,
- All petroleum consumed in the United States is valued at a post-1973 embargo price of $10 per barrel.
- External costs are estimated indirectly by establishing a relationship between changes in GNP and the U.S. demand for energy. For the period 1950–72, petroleum accounts for about 46 percent of the gross energy used. This relationship then permits, based on the best estimate of experts, an approximate determination of the loss in GNP resulting from an interruption of imports of petroleum.
- The probabilities of varying levels and durations of import interruption have been specified for situations with and without a stockpile. These probabilities are shown in table V–1.

The estimation of probabilities consists of two steps: first, to define the range of possible import interruptions; and second, to estimate the probability of an event occurring in each interval of the range of interruptions. It is important to note that the selected intervals of interruption span both the percentage and duration of the spectrum of possible interruptions. The discrete interruptions used in the following calculations are the median points of the intervals and represent the interval in which they occur,

For SP–1 the probability estimates considered the following factors with respect to the material under review: the existence or nonexistence of a carte]; the likelihood. of an effective cartel 1ike OPEC; and the likelihood of unilateral political actions,

That other cartels could be formed is influenced by such actions as are oc-

Table V–l.—Probability of cartel action without a stockpile*

‘/0 Import Interruption	i	Months of Duration: o	0-2	2-4	4-8	8	Total
No Interruption							0.0
	k		1	2	3	4	
0-1o	1		0.0	0.0	0.0	0.0	0.00
10-40	2		0.0	0.36	0.27	0.0	0.63
40-60	3		0.0	0.27	0.1	0.0	0.37
60-100	4		0.0	0.0	0,0	0.0	0.0
Total			0.0	0.63	0.37	0.0	1.00

● Precision on the probability values is due to the averaging of values specified by three or more material specialists.

Probability of cartel action with stockpile Q_1*

‘/0 Import Interruption	i	Months of Duration: o	o-2	2-4	4-8	8	Total
No Interruption		0,70					0.70
	k		1	2	3	4	
0-1o	1		0.0	0.0	0.0	0.0	0.0
10-40	2		0.0	0.05	0.10	0.0	0.15
40-60	3		0.0	0.10	0.05	0.0	0.15
60-100	4		0.0	0.0	0.0	0.0	0.0
Total		0.70	0.0	0.15	0.15	0.0	1.00

● (Q_1=250 Mil bbl)

Probability of cartel action with stockpile Q_2*

% Import Interruption	i	Months of Duration: o	0-2	2-4	4-8	8	Total
No Interruption		0.91					0.91
	k		1	2	3	4	
0-1o	1		0.0	0.0	0.0	0.0	0.0
10-40	2		0.0	0.0	0.02	0.0	0.02
40-60	3		0,0	0.02	0.05	0.0	0.07
60-100	4		0.0	0.0	0.0	0.0	0.0
Total		0.91	0.0	0.02	0.07	0.0	1.00

● (Q2=500 Mil bbl)

Probability of cartel action with stockpile Q_3*

‘/0 Import Interruption	Months of Duration	Total
No Interruption		1.0
Total		1.0

*(Q_3=1 Bil bbl

curring now with respect to chromite. Shipments of chromite from Rhodesia to the United States have been hindered more and more by slowdown tactics in neighboring Mozambique. Rhodesia is landlocked and forced to ship by rail to ocean ports in Mozambique. Ships have been known to depart half loaded with chromite after 70 days of loading. This has become more forceful, and sanctions are being invoked by the United Nations.

b. Input Values.—The values for the input variables to the computer program for SP–1 are listed in table V–2. This table lists the mathematical symbol, the name or description of the variable, the units of measure, and the numerical value of the input variable for each. The calculations for SP-1 were performed by computer program for the input variables listed in table V–2.

c. Calculated (Output) Values.—The values for the output variables calculated by computer program for SP–1 are listed in table V–3. This table lists the mathematical symbol, the description of the variable, and the numeral value of the output variable for each stockpile j.

d. Graphic Representation of the Calculation.—Figure V–3 is a graphic representation of the calculated costs, benefits, and net benefits for the SP–1. The values were com-

Table V–2.—Input Variables SP–1

Math Symbol	Progran Symbol	Description	Units	Either not dependent on J, or J=1	J=2	J=3
Q_j	Q	Stockpile size	Million Barrels	250.	500.	1000,
c .	Cu	Unit Cost	$ per Barrel	10.00	10.30	11.
c_f	CF	Fixed initialization cost	Million $	0.5		
c“	CV	Variable initialization cost	$ per Barrel	5.		
	XI	Interest rate	Percent per year	0.08		
d	SLR	Spoilage loss rate	Percent per year	0.0		
s	SC	Storage cost	$ per Barrel per year	1.0		
c_d	CD	Unit disposal cost	$ per Barrel per year	0.0		
P	P	Price	$ per Barrel	10.00		
P':	PP	Increased price	$ per Barrel	10.0	10.3	11.0
1	D	U.S. demand at price p	Million Barrels	6010.		
d'j	DP	U.S. demand at price p'	Million Barrels	6010.	5969.	5872.
s	S	U.S. supply at price p	Million Barrels	4010.		
s'j	SP	U.S. supply at price p'	Million Barrels	4010.	4010.	4010,
EC_j	EC	External cost	Million $	0.0	873.270	2923.5
R	R	Risk aversion factor	Coefficient	0.0		
$c\ g_j$	CG	Capital gains	Million $	0.0	0.0	0.0
Q_{dj}	QD	Stockpile disposal	Million Barrels	0.000	.000	.000

Math Symbol	Progran Symbol	Description	Units	J=1	K=1	K=2	K=3	K – 4
ED_{ik}	ED	External damage - no stockpile	Million $	1=1	.000	.000	.000	.000
				1=2	.000	11863.00	23458.00	.000
				1=3	.000	23458.00	47458.00	.000
				1=4	.000	.000	.000	.000
P'_{ik}	PWOS	Price without stockpiling	$ per Barrel	J = I				
				1=1	10.0	10.0	10.0	10.0
				1=2	10.0	12.0	14.0	10.0
				1=3	10.0	11.75	13.3	10.0
				1=4	10.0	10.0	10.0	10.0
S'_{ik}	SWOS	Supply without stockpiling	Million Barrels	J = I				
				1 = 1	4010.	4010.	4010.	4010.
				1=2	4010.	4010.	4010.	4010.
				1=3	4010.	4010.	4010.	4010.
				1=4	4010.	4010.	4010.	4010.
d'_{ik}	DWOS	Demand without stockpile	Million Barrels	J = I				
				1=1	0.0	0.0	0.0	0.0
				1=2	0.0	5885.0	5760.0	0.0
				1=3	0.0	5760.0	5510.0	0.0
				1=4	0.0	0.0	0.0	0.0

Table V–2.—Input Variables SP-1—continued

				J=l	K=l	K=2	K=3	K – 4
P'_{ik}	PROB	Probability of cartel action without stockpile	Percent per year	J=1				
				1=1	0.0	0.000	0.000	0.00
				1=2	0.0	0.364	0.273	0.00
				1=3	0.0	0.273	0.090	0.00
				1=4	0.0	0.000	0.000	0.00
ED_{ijk}	EDP	External damage - with stockpile	Million $	J=1				
				1=1	0.000	0.000	0.000	0.000
				1=2	0.000	0.000	0.000	0.000
				1=3	0.000	0.000	47458.000	0.000
				1=4	0.000	0.000	0.000	0.000
				J=2				
				1=1	0.000	0.000	0.000	0.000
				1=2	0.000	0.000	23458.000	0.000
				1=3	0.000	23458,000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000
				J=3				
				1=1	0.000	0.000	0.000	0.000
				1=2	0.000	11863.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000
P'_{ijk}	PWD	Price with disposal of stockpile j	$ per Barrel	=1,2.3				
				1=1	10.0	10.0	10.0	10.0
				1=2	10.0	10.0	10.0	10.0
				1=3	10.0	10.0	11.65	10.0
				1=4	10.0	10.0	10.0	10.0
S''_{ijk}	SWD	Producer supply with disposal of stockpile j	Million Barrels	=1,2,3				
				1=1	4010.	4010.	4010.	4010.
				1=2	4010.	4010.	4010.	4010.
				1=3	4010.	4010.	4010.	4010.
				1=4	4010.	4010.	4010.	4010.
d''_{ijk}	DWD	Demand with disposal of stockpile	Million Barrels	=1,2,3				
				1=1	6010.	6010.	6010,	6010.
				1=2	6010.	6010.	6010.	6010.
				1=3	6010.	6010.	5980.	6010.
				1=4	6010.	6010.	6010.	6010.
P'_{ijk}	PRCBP	Probability of cartel action with stockpile Q_j	Percent per year	J=1				
				1=1	0.000	0,000	0.000	0.000
				1=2	0.000	0.050	0.100	0.000
				1=3	0.000	0.100	0.050	0.000
				1=4	0.000	0.000	0.000	0.000
				J=2				
				1=1	0.000	0.000	0.000	0.000
				1=2	0.000	0.000	0.020	0.000
				1=3	0.000	0.020	0.050	0.000
				1=4	0.000	0.000	0.000	0.000
				J=3				
				1=1	0.000	0.000	0.000	0.000
				1=2	0.000	0.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000

Table V-3.—Calculated results for SP–1

Symbol	Description	Economic impacts of stockpiling petroleum (Billions of dollars)* J=l 250,000	J=2 (Millions of barrels) 500,000	J=3 1,000,000
NB_j	Net benefits	19.1	19,0	14.5
B:	Benefits function	20.8	23.9	26.3
C:	Cost function	1.7	4.9	11.7
E(DN)	Expected damage not averted	5.4	2.4	.000
	Benefit variables:			
	With stockpiling:			
$E(PL'_j)$	Expected producer loss	3.1	1.1	0.000
$E(CS'_j)$	Expected consumer savings	4.44	1.6	.000
$E(ED'_j)$	Expected external damage	2.4	.9	.000
	Without stockpiling:			
$E(PL_j)$	Expected producer loss	7.1	9.3	10.4
$E(CS_j)$	Expected consumer savings	10.3	13.7	15.3
$E(ED_j)$	Expected external damage	13.7	18.1	21.4
	Cost variables:			
HC_j	Holding costs	.5	.9	1.9
	Initialization costs	1.3	2.5	5.0
LEWj	Loss in economic welfare	.000	.6	1.9
CL_j	Consumer loss	.000	1.8	5.8
PG_j	Producer gain	.000	1.2	4.0
DC_j	Disposal cost	.000	.000	.000
OC_j	Operating costs	4.2	8.6	17.9
AC_j	Acquisition costs	2.5	5.2	11.0
**	Economic impact of no stockpile	20.8	23.9	26.3

● All calculations have been rounded for simplicity

**The economic impact of no stockpile is equivalent to the benefits (expected damages averted) attributed to the stockpile which are foregone in the absence of the stockpile,

puted for only three stockpile sizes and zero stockpile.

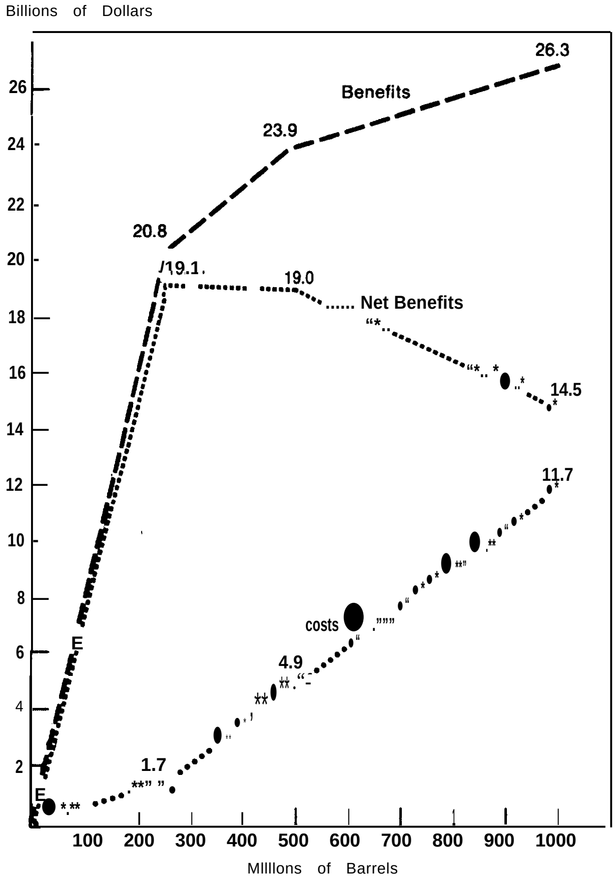
e. Optimal Stockpile Size.—The net benefit curve in figure V-3 can be used to indicate the probable optimal stockpile size, where the curve appears to be at a maximum positive value (or minimum negative value). Although this can only be taken as an indication of the area of an optimal quantity, it illustrates the desired value of the stockpile size for the values of the input variables chosen.

The calculations resulted in an optimal stockpile size of 250-500 million barrels accumulated over a l-year period. The economic net benefits expected for this stockpile will be approximately $19 billion. It should be emphasized that the estimates apply only to the specific materials examined and within the scenario assumptions described, and should therefore not be taken to indicate that precise quantities of specific materials should or should not be stockpiled. Nevertheless, the nature and magnitude of the estimates are sufficient to indicate that an economic stockpile should be given detailed consideration as one component of a more comprehensive national materials policy and that measuring the benefits or costs of a supply disruption in terms of the probability, rather than the certainty, of a disruption will significantly reduce the quantity of material to be stockpiled,

As a measure of scale for the results of these calculations, two current stockpiling proposals can be examined. The first proposal, Title II of

Figure V-3.

Economic Net Benefits of SP-1



the Administration's Energy Independence Act (IEP)—the National Strategic Petroleum Reserve (Civilian) Act of 1975—proposes the establishment of a strategic petroleum reserve of 1 billion barrels' reserve for the military. The second proposal is part of the requirements for allocation rights under the International Energy Agency which stipulates that each participating country maintain emergency oil reserves sufficient to sustain consumption for 60 days with no net imports. For the United States, which presently is importing 5,5 million barrels per day, satisfaction of this obligation would require a stockpile of 330 million barrels. The IEP also calls for demand curtailment measures which would reduce consumption by 7 percent in the event of an embargo--or 67 1/2 million barrels over a 60-day period.

In this example, the optimal stockpile size of 250–500 million barrels was based on the probability of four distinct cartel/unilateral actions and the damages which would result from each action (i.e., a 6-month, 50-percent import interruption; and a 3-month, 25-percent import interruption; a 3-month, 50-percent interruption; and a 3-month, 25-percent import interruption). At the lower end of the scale this stockpile size falls short of the IEP requirement by a minimum of 10 percent and is approximately 25 percent the size of the NSPR act's proposed stockpile. It is interesting to note that both the IEP requirement and that calculated with the Decision Criteria for SP-1 are approximately one-third of the possible total petroleum import interruption of 1 billion barrels for a 6-month period,

In summary, the example calculations for SP–1 indicate that the stockpile size should be based upon the expected economic net benefits of the stockpile. The example calculations also show that a stockpile based upon the probability of an interruption is significantly smaller than one based on the certainty of total interruption.

These calculations also illustrate the role of the risk aversion factor. It should be noted, for example, that the difference in economic net benefits for stockpile sizes of 250 and 500 million barrels is relatively small ($140 million). Yet the protection provided by the larger stockpile in the event of a cartel action is substantially greater, The risk aversion factor has been treated as an unknown, and the value of r which equates the economic net benefits for the two stockpile sizes has been solved. The resulting small value of 1.007 suggests that implementation of the larger stockpile should be given serious consideration. If the value for r were equal to say, 3,5, such a high-risk aversion would most likely be questioned.

f. Sensitivity Analysis for SP–1.—This section is a discussion of the particular sensitivity analysis of SP–1. An examination of table V-4 indicates the economic net benefits to be fairly insensitive to any input variable per-

Table V-4.-Percent change based on 10 percent perturbation of variables for SP–1

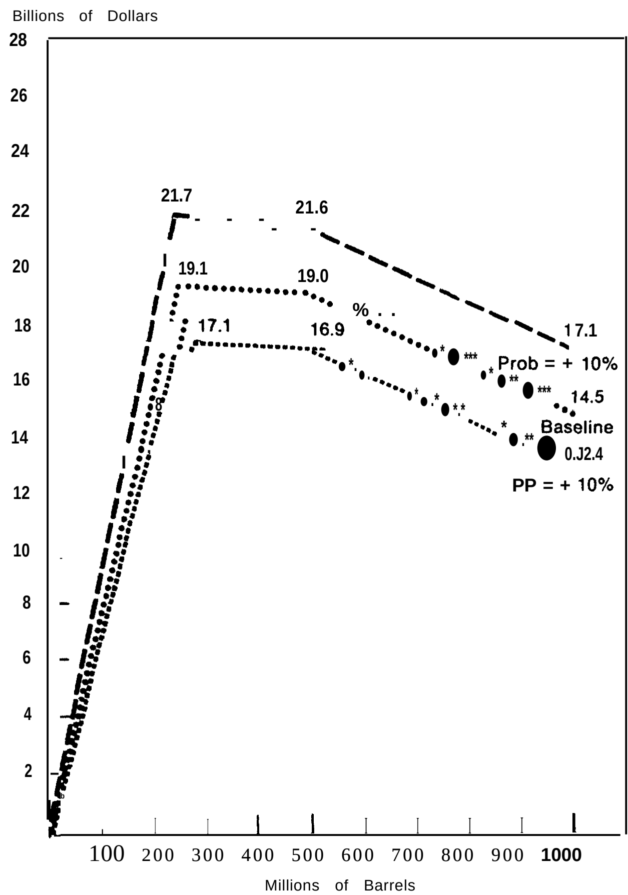
Perturbed* variable	Benefits			cost			Net benefits		
	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3
CF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cv	.00	.00	.00	7,35	5.12	4.26	–.65	–1.31	–3.44
Cu	.00	.00	.00	1.18	.84	.75	–.10	–.22	–.61
Sc	.00	.00	.00	1.47	1.02	.85	–.13	–.26	–.69
EC	.00	.00	.00	.00	1.79	2.49	.00	–.46	–2.01
ED	6.60	7.57	8.14	.00	.00	.00	7.18	9.51	14.72
PROB	12.61	10.99	10.00	.00	.00	.00	13.73	13.81	18.07
PROBP	–2.61	– .99	.00	.00	.00	.00	–2,84	–1.25	.00
PP	.00	.00	.00	117.61	41.78	18.10	–10.45	–10.72	–14.61
D	2.53	2.91	2.97	.00	1.85	2.56	2.76	3.18	3.30
s	–1 .69	–1.94	–1 .98	.00	–1.23	–1.71	–1,84	–2.12	–2.20
SWD	–.73	– .23	.00	.00	.00	.00	–.79	–.30	.00
DWD	1.09	.35	,00	.00	.00	.00	1.18	.44	.00
EDP	1.14	.39	.00	.00	.00	.00	1.24	.49	.00

● See table V–2 for definition of variables

turbation (a + 10-percent change in probability, external damage, or increased price result in changes of only –7 to +18 percent in the economic net benefits). Using this table as a guide, the actual computed economic net benefits for the baseline, probability, and increased price perturbation runs were plotted as shown in figure V-4, Examination of this figure shows that the range of stockpile sizes for achieving maximum benefits still lies in the 250- to 50()-million-barrel range. The figure also indicates two further conclusions:

- Given an increased probability of a cartel action without a stockpile, the optimal stockpile size increases to 600 or 700 million barrels.
- Given an increased price of petroleum, the optimal stockpile size does not significantly change.

Figure V-4.
Perturbations for SP-1



4. Discussion of Partial Economic Benefits and Costs for Each Phase of Stockpile Operation for SP-1

So far, the Economic Welfare Model has been employed to estimate the aggregate

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economic benefits and costs to the U.S. economy (society) as a result of stockpiling petroleum. However, the model can also be extended to estimate the economic benefits and costs for each phase of stockpile operation-acquisition, holding and disposals well as the distribution of economic benefits and costs between consumers and producers. As the examples in this assessment demonstrate, the distributive effects of economic stockpiling can be significant, and given the policy concerns within the United States for the distribution effects of programs and policies, it is appropriate for the Economic Welfare Model to address them explicitly.

In this assessment, four categories of distributive effects are identified: consumers, producers, the stockpile operator (presumably the Federal Government), and external costs. In the application of the Economic Welfare Model, further disaggregation (such as by discrete income classes, employment groups or regions) may be desirable.

The direct benefits and costs of stockpiling petroleum associated with each of the categories are presented in four individual tables immediately below. It is important to note that insofar as transfer payments between consumers and producers are incorporated, these benefits and costs differ from those estimated earlier. As will be seen, these transfer payments can be substantial,

a. Direct Benefits and Costs to Materials Producers.—Direct benefits and costs to materials producers as a result of a petroleum stockpile under SP-1 are summarized below:

Benefits and costs to producers		Stockpile size (Millions of bbl)		
Operational action	Type of benefit or cost	[illegible]	500,000	1,000,000
		(Billions of dollars)		
Acquisition	Producer gain (PG)	0.00	1.2	4.0
Holding	Producer loss E (PL)*	7.0	9.3	10.4
Disposal	Producer loss E (PL')*	3.0	1.1	0.00

● These terms are expressed as expected values, i.e., they have been weighted by probabilities,

b. **Direct** Benefits and Costs to Materials Consumers.—Direct benefits and costs to materials consumers as a result of a petroleum stockpile under SP-1 are summarized below:

Benefits and costs to consumers		Stockpile size (Millions of bbl)		
Operational action	Type of benefit or cost	250,000	500,000	1,000,000
		(Billions of dollars)		
Acquisition	Consumer loss (CL)	0.00	1.8	5.9.
Holding	Consumer savings E (CS)*	10,3	1.4	15.3
Disposal	Consumer savings E (CS')*	4.4	1.6	.000

● These terms are expressed as expected values, i.e., they have been weighted by probabilities.

c. **Costs** and Benefits to the Stockpile Investor.—The costs and benefits to the stockpile investor for an economic stockpile of petroleum under SP–1 are summarized below:

Revenues and costs to stockpile operators		Stockpile size (Millions of bbl)		
Operational action	Type of benefit or cost	250,000	500,000	1,000,000
		(Billions of dollars)		
acquisition	Initialization cost (IC)	1.3	2.5	5.0
Holding	Holding cost (HC)	.5	.9	1.9
Disposal	Disposal cost (DC)	.000	.000	.000
	Capital gains (CG)	.000	.000	.000

d. **Estimation** of External Costs and Damages.—The estimation of external costs and damages can be done in a generalized first-order approximation, or it can be rigorously determined. The illustrative calculations for a petroleum stockpile under SP-1 utilize the first approach, a general approximation. The resulting external benefits and costs as given in the petroleum example are summarized below:

External costs and damages		Stockpile size (Millions of bbl)		
Operational action	Type of benefit or cost	250,000	500,000	1,000,000
		(Billions of dollars)		
Acquisition	External cost (EC)	0.000	.9	2.9
Holding	External damage E (ED)*	13.7	18.1	21.4
Disposal	External damage E (ED')*	2.4	.9	.000

"These terms are expressed as expected values.i.e., they have been weigbted by probabilities.

The external damage is the expected external damage, Therefore:

$$(ED_j) = \sum_i \sum_k (P_{ijk} - P'_{ijk}) ED_{ijk} \quad (14a)$$

and

$$(ED'_j) = \sum_i \sum_k P'_{ijk} ED'_{ijk} \quad (14b)$$

Estimation techniques for external costs and damages can be based on proxies or indicators. A general approximation of external costs based upon proxy variables or other indicators provides quantifiable values which can be applied using the Economic Welfare Model. For an economic stockpile of petroleum under SP–1, the proxy variable used in the illustrative calculations was gross national product (GNP). The relationship determined from historical data was that a percentage change in the gross energy product (GEP) of the United States reflected an equivalent *percentage* change in the GNP. The base period data for 1973 indicated that 46 percent of the GEP was attributable to petroleum and the GNP was $1.3 trillion, while the consumption of petroleum was 6.3 billion barrels, Thus, a 10-percent drop in the annual petroleum consumption (630 million barrels) would cause a 4.6-percent decrease in the GNP, or $59.8 billion.

5. Summary of Economic Net Benefits and Partial Benefits for SP–1

The operation of an economic stockpile consists of three types of action—acquisition, holding, and disposal—as discussed in the section on the conceptual logic of stockpiling in chapter 111. Each of these actions generates economic benefits and costs to the U.S. economy which must be identified and analyzed. Table V–5 is a tableau which relates the types of economic benefits and costs with the individual actions in the operation of an economic stockpile. The tableau may be explained as follows: first, the economic net benefits to the United States of a particular stockpiling policy may be defined as the net algebraic addition of all the terms in the tableau related to that policy; second, the separate terms under each operational phase indicate the partial economic benefits and costs for the four categories of economic impacts. The economic benefits and costs to the materials producers and consumers do not include those portions of the economic benefits and costs to the stockpile operator and the external costs which are ultimately borne by these two interest groups.

The results of the calculations for SP-1 are summarized in table V-6. These results are for the initial year of operation and include heavy operating costs for acquisition and substantial impacts on producers and consumers associated with acquisition and holding,

Table V–5.—Economic benefits and costs of economic stockpiling arrayed by operational action

Types of economic benefits and costs	SP	Operational actions					
		Acquisition		Holding		Disposal	
		Terms	Eq.	Terms	Eq.	Terms	Eq.
Direct benefits and costs to materials producers	1	PG	3	PL	14	PL’	12
	2	PG	3	PL		PL	13a
	3	APs	28	PL		APS	28
	4	PC	19a	PL		PL	19e
	5	APS	26	PL		APS	26
Direct benefits and costs to materials consumers	1	CL	3	CS	14	CS’	12
	2	CL	3	CS		CS’	13b
	3	CL	29	CS		CS’	29
	4	CL	19b	CS		CS	19d
	5	CL	24	CS		CS’	24
Indirect benefits and costs borne by stockpile operator*	1	IC	2	HC	5	DC	6
	2	IC	2	HC	5	DC	6
	3	IC	2	HC	5	DC+CG	25
	4	IC	2	HC	5	DC+CG	20
	5	Ic	2	HC	5	DC+CG	25
External benefits and costs	1	EC	7	ED	13	ED’	11
	2	EC	7	ED		ED’	17
	3	ED’	28	ED		ED’	28
	4	EC	7	ED		ED	20
	5	ED’	23	ED		ED’	23

Table V–6.—Partial benefits and costs of SP–1 for first year of operation
[In Billions of dollars]

Type of benefit or cost	Size of stockpile [Millions of bbl]	Operational action		
		Acquisition	Holding	**Disposal**
		PG_j	$E(PL_j)$	$E(PL'_j)$
Producers. ., ...	250	$0.0	-$7.0	-$3.0
	500	1.2	-9.3	– 1.1
	1000	4.0	-10.4	-0.0
		CL_j	$E(CS_j)$	$E(CS'_j)$
Consumers.	250	0.0	10.3	4.4
	500	-1.8	13,7	1.6
	1000	-5.9	15.3	
		I C	HC_j	$(DC_j\text{-}CG_j)$
Stockpile operator	250	–1.3	- 0.4	0.0
	500	–2.5	– 0.9	0.0
	1000	–5.0	- 1.9	0.0
		EC_j	E (ED $_j$	$E(ED'_j)$
External costs (benefits),	250	0.0	13.7	2.4
	500	-0.9	18.1	0.9
	1000	-2.9	21.4	0.0

Net benefits are 19. I millions, 19.0 millions, and 14.5 millions for 250-, 500-, and 10() -mbbl stockpile, respectively.

In this particular case, the result of stockpiling yields significant gains to consumers and losses to producers, which can be interpreted as a transfer of resources from producers to consumers. The magnitude of transfers from producers to consumers declines as the size of the petroleum stockpile increases, explained in this example principally by changes in the probabilities of cartel action associated with each stockpile size. For comparison, table V-7 illustrates the terms in the benefit and cost functions for the second year under the assumption that the prices, elasticities, and cartel probabilities are the same. It should be noted that economic net benefits are expressed in their present value. Since these net benefits are realized in a future time period, it is appropriate that they be discounted to present value. A discount rate of 8 percent has been used. The values for all other terms in table V–7 have not been discounted. In practice, the stockpile operator would periodically reassess probabilities (and other data) for cartel operation and recalculate estimated economic net benefits. The results might cause the operator to increase or decrease the stockpile size with attendant economic impacts.

The data in tables V-6 and V–7 provide the basis for assessing the effects of a petroleum stockpile as follows, The cost to the Government of establishing a 250-million-barrel stockpile is estimated to be about $4.20 billion in the first year, with the major components being $2.5 billion for purchase of oil plus $1.25 billion for purchase of storage and other facilities, In each succeeding year the cost of operation would be about $450 million if the stockpile size remained unchanged. In return for this expenditure, the estimated economic net benefits to the United States would be approximately $19.1 billion in the first year. In the second year, economic net benefits change as initialization costs are deducted and the new net benefits are discounted to their present value at a discount rate of 8 percent.

Table V–7.—Partial benefits and costs of SP–1 for second year of operation

In millions of dollars

Type of benefit or cost	Size of stockpile [Millions of bbl]	Operational action: Holding	Operational action: Disposal
		$E(PL_j)$	$E(PL'_j)$
Producers	250	-$7.0	-$3.0
	500	-9.3	- 1.1
	1000	-10.4	0.0
		$E(CS_j)$	$E(CS'_j)$
Consumers	250	$10.3	$4.4
	500	13.7	1.6
	1000	15.3	
			$(DC_j-CG_j$
Operators	250	-$.04	$0.0
	500	-0.9	0.0
	1000	-1.9	0.0
		$E(ED_j)$	$E(ED'_j)$
External	250	$13.7	$2.4
	500	18.1	0.9
	1000	21.4	0.0

The present value of net benefits are 18.9 millions, 21.3 millions, and 22.6 millions for 250-, 500-, and 1000-mbbl stockpile, respectively.

C. ECONOMIC IMPACTS OF STOCKPILING TO CUSHION THE IMPACTS OF NONPOLITICAL IMPORT DISRUPTIONS (SP–2)

The procedure for calculating the benefits of SP-2 is identical to that developed for the second benefit component of SP-1, i.e., the benefits derived from the counteraction of a supply interruption after it has occurred. The cost function for SP-2 has been described in the section in chapter IV on the Economic Welfare Model, equation (7). The benefit function for SP-2 is developed immediately following subsequent paragraphs, and calculations of the net benefits are presented thereafter.

1. Derivation of Benefit Function for SP-2

Like SP-1, the benefits derived from SP-2 over the coming time period depend upon the specific import disruptions which will restrict supplies of a material. The benefits for SP–2 should be determined on the basis of expected benefits obtained from a stockpile of a given size. These benefits are equal to the damage that the stockpile could offset multiplied by the probability that the disruption will occur. These benefits must be determined for each possible import interruption. The benefit function for SP-2 is given as:

$$B_j = (1+r)\,[D'_{ijk}P_{ik}] \qquad (15)$$

where

B_j = benefits derived from stockpile j

risk aversion factor

D'_{ijk} damage offset by stockpile j

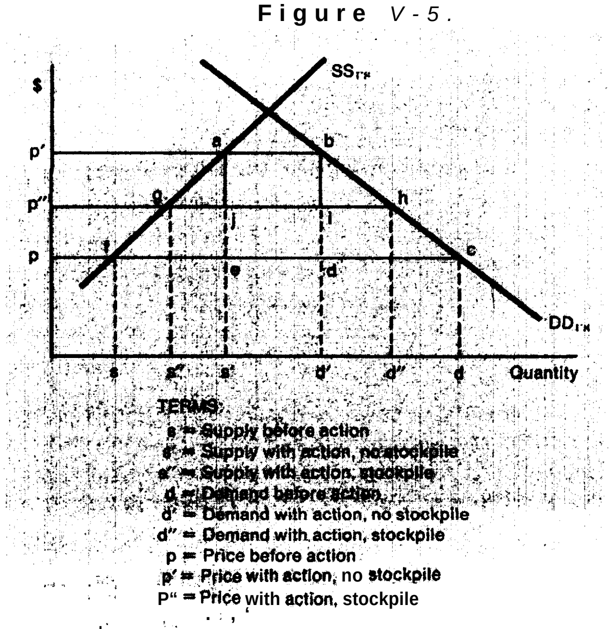
P_{jk} = probability of the interruption occurring
i = the percent import disruption
k = the duration of the disruption in months

The ‘benefits for each stockpile examined (i.e., stockpiles of size Q_j) can be determined from equation (15), given the risk aversion factor (1+r) which reflects society’s reluctance to be exposed to the import disruption, the probability (P_{ik}) that a specified interruption will occur, and the damages (D'_{ijk}) which can be offset by the stockpile when the interruption occurs.

The damage which can be offset by a stockpile depends upon the size of the interruption and the size of the stockpile. Figure V-5 illustrates the effect of a decrease in imports upon the domestic market. The damage incurred by the country is twofold: a loss of consumer surplus and the external costs imposed upon society.

Figure V-5 shows the price rise associated with an import disruption (i. e., the price rises from p to p’). The effect of releasing stocks is to lower the price to p“. If the stockpile is of sufficient size, the disposal of stocks can completely offset the import disruption (i.e., p“=p) The loss of consumer surplus which is offset by disposal of the stockpile is shown in figure V-5 as the trapezoid abhg. As pointed out in the general discussion of the cost function, the actual loss to domestic consumers which is offset is p’bhp, an amount which could appreciably exceed abcf. The difference, however, goes to domestic producers as a transfer payment and does not represent a loss of real resources to the country.

Figure *V-5.*



As pointed out in the discussion of the cost function in chapter IV, a price rise may impose in addition to the loss in net consumer supplies, external costs on society which are not borne by the consumers of the material, For as the latter cut back their production, their suppliers may be hurt and their employees laid off. The benefits which a stockpile produces by avoiding or reducing these external costs should be counted in the benefit function. Capital gains (or losses) resulting from the disposal of stocks are added to (subtracted from) the damages in the benefit fulnction.

The damage offset through disposal of a stockpile of size Q o is calculated from equation (15) which is simil ar in form to equation (13c) of SP–1:

$$D'_{ijk} = 1/2(s'_{ik} - s''_{ijk})(p'_{ik} - p''_{ijk}) + 1/2(d''_{ijk} - d'_{ik})(p'_{ik} - p''_{ijk}) + (d'_{ik} - s'_{ik})(p'_{ik} - p''_{ijk}) + ED_{ijk} \quad (16)$$

where

D'_{ijk} = damage offset by the stockpile
s'_{ik} = supply when the interruption occurs without stockpiling
s''_{ijk} = producer supply with disposal of the stockpile j
p'_{ik} = price when the interruption occurs without stockpiling
p''_{ijk} = price with disposal of the stockpile j
d'_{ik} = demand when the interruption occurs without stockpiling
d'_{ijk} = demand with disposal of the stockpile j
E D_{ijk}=eXternal damage, the external costs saved by the disposal of the stockpile j

The first term on the right-hand side of this equation estimates the saving in consumer surplus which arises because domestic producers incur a smaller increase in real incremental costs due to the fact that their output increases only to s“ rather than s’. As figure V-5 illustrates, this savings, which is reflected by the triangle ajg, is equal to one-half the increase in domestic supply which did not take place due to stockpile releases multiplied by the increase in domestic price which was prevented. The product of the prevented increase in domestic supply and price is multiplied by one-half, on the assumption that the domestic supply curve is approximately linear in the price range p“ to p’.

The third term of equation (15) represents the saving in consumer surplus which arises because the price paid to foreign producers is kept at p“ rather than being permitted to rise to p’. This saving is reflected in figure V-5 by the rectangle abij, It can be estimated by the product of the prevented price increase and the level of imports which would occur at the price p’,

The fourth term, ED, reflects the saving produced by the stockpile in the external costs which are not borne by the users of the material. The first three terms can be approximated on the basis of estimates of the prevented price increase (p’ – p“) and the elasticities of domestic supply and demand which apply for the time period and price range being considered. Estimates for ED must be based on other relationships.[12]

The sum of the probabilities that import interruptions will occur cannot exceed 1 and must encompass the entire spectrum of possible import interruptions. The expected benefit of a stockpile of a size Q_j can then be calculated from equation (15), once the damage offset by disposal of the stockpile during a possible interruption has been estimated, and society’s risk aversion factor has been specified. The calculations described above should be repeated for stockpiles of various sizes in order to trace out the entire benefit function,

2. Estimation of Economic Net Benefits for SP-2

The following discussion is a presentation of the estimated economic net benefits of stockpiling zinc for SP–2. Although the reserves of zinc are distributed worldwide, the supply to the United States is concentrated in a few countries, Canada and Mexico being dominant, with these imports constituting roughly one-half of the total U.S. consumption. A nonpolitical action, such as a strike in the highly unionized zinc mining industry in Canada, could temporarily interrupt imports to the United States which would not be offset through increased imports from other sources.

a. Background Information.—Several of the important values and assumptions used in the estimation of net benefits of stockpiling for SP–2 are outlined below:

- Based on supply-demand relationships during the period of 1969–71—when U.S. production remained relatively constant, prices rose, and imports and total demand fell—an implicit price elasticity of demand for zinc falls in the range of -0.5 and -0.7, This range of price responses was retained in the computation with some reduction for short-term interruptions (o–3 months).
- U.S. demand of 1,500,000 tons, U.S. supply of 750,000 tons, U.S. imports of 750,000 tons and a unit price of $720 were retained as the baseline values for the computations,
- It is assumed that acquisition of zinc for the stockpile will come solely from additional imports, which in turn implies no external cost during the acquisition phase,

[12] The external costs (and external damages) are frequently a significant portion of the costs and expected benefits derived from stockpiling. These external costs are also the most difficult to determine, Simplified, first-order approximations of the external costs can be made as shown in this section

- Probabilities of a temporary interruption of zinc imports were specified for two durations and four levels, as shown in the following table.

Duration in months	Probabilities: Percent interruption 0	0-10	10-25	25-50	50-100
0	0.58				
0–3		0.25	0.10	0.05	0
3–12		0.02	0	0.05	0
Total	0.58	0.27	0.1	0.1	0

For SP–2 the probability estimates considered the following factors with respect to the material under review: (1) as it pertains to strikes, the nature and history of labor union organization in producing countries and in transportation lines—railroad and ocean shipping; as it pertains to natural disasters, the concentration of supply in various geographical areas particularly subject to such events; and (2) as it pertains to nonnatural (manmade) disasters, the concentration of supply in industrial organizations.

Two illustrations will clarify the history of materials problems which might be alleviated with SP–2, A fire at the U.S. 'S largest silver mine, the Sunshine Mine at Kellogg, Idaho, in May 1972 killed 91 men. The mine was closed for 7 months and this resulted in a drop of 10 percent of the U.S. mine output that year. A strike lasting almost 6 months at the largest nickel mine in the world at Sudbury, Canada, in 1969 resulted in loss of production of about one-third Canadian output for the year. This was somewhere between 7–10 percent of the world's supply.

b. Input Values.—The-values for the input variables to the computer program for SP–2 are listed in table V–8. This table lists the mathematical symbol, the name or description, of the variable, the units of measure, and the value of the input variable for each I, J, and K. The calculations for SP–2 were performed by the computer program using the input variables listed in table V–8.

c. Calculated (Output) Values.—The values for the output variables calculation by the computer program for SP–2 are listed in table V-9. This table lists the mathematical sym-

Table V–8.—Input variables SP–2

Math symbol	Program symbol	Description	Unit	Either not dependent on J, or J=1	J=2	J=3
Q_j	Q	Stockpile size	Million tons	0.05	0.10	0.15
CU_j	CU	Unit cost	$ per ton	720.	720.	792,
C_f	CF	Fixed initialization cost	Million $	0.5		
c“	CV	Variable initialization cost	$ per ton	0.0		
	XI	Interest rate	Percent per year	0.00		
d	SLR	Spoilage loss rate	Percent per year	0.0		
s	SC	Storage cost	$ per ton per year	0.1		
C_d	CD	Unit disposal cost	$ per ton per year	0.0		
p	P	Price	$ per ton	720.		
P!	PP	Increased price	$ per ton	720.	720.	792.
d^1	D	U.S. demand at price p	Million tons	1.5		
d!	DP	U.S. demand at price p'	Million tons	1.5	1.5	1.0815
s^1	s	U.S. supply at price p	Million tons	0.75		
s_j	SP	U.S. supply at price p'	Million tons	0.75	0.75	0.75
EC	EC	External cost	Million $	0.0		
R	R	Risk aversion factor	Coefficient	0.0		
CG_j	CG	Capital gains	Millions $	0.0		
Q_{dj}	QD	Stockpile disposal	Million tons	0.0		

Table V–8.—Input variables SP–2— continued

Math symbol	Program symbol	Description	Unit	[illegible]	[illegible]	[illegible]	K=3	K=4
ED_{ik}	ED	External damage-no stockpile	Million $	1=1	0.000	0.000	0.000	0.000
				1=2	0.000	0.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000
				J=1				
P_{ik}	PWOS	Price without stockpiling	$ per ton	1=1	756,000	864.000	1008.000	720.000
				1=2	792.000	720.000	720.000	720.000
				1=3	720.000	720.000	720.000	720.000
				1=4	720.000	720.000	720.000	720.000
				J=1				
S'_{ik}	SWOS	Supply without stockpiling	Million tons	1=1	0.750	0.750	0.750	0.750
				1=2	0.750	0.750	0.750	0.750
				1=3	0.750	0.750	0.750	0.750
				1=4	0.750	0.750	0.750	0.750
				J=1				
d'_{ik}	DWOS	Demand without stockpile	Million tons	1=1	1.481	1.454	1.407	0.000
				1=2	1.425	0.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000
				J=1,2,3				
P_{lk}	PROB	Probability of interruption without stockpile	Percent per year	1=1	0.250	0,100	0.050	0.000
				1=2	0.020	0.000	0.000	0.000
				1=3	0.000	0.000	O.000	0.000
				1=4	0.000	0,000	0.000	0.000
				J=1				
ED'_{qk}	EDP	External damage-with stockpile	Million $	1=1	7,484	21.646	45.338	0.000
				1=2	39.854	0.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000
				J=2				
				I=1	7,484	21.645	83,878	0.000
				I=2	58.934	0.000	0.000	0.000
				I=3	0.000	0.000	0.000	0.000
				I=4	0.000	O.000	O.000	0.000
				J=3				
				1=1	7.484	21.646	83.876	0.000
				1=2	58.984	0.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000
				J=1				
P'_{ijk}	PWD	Price with disposal of stock-pile j	$ per ton	1=1	720.000	720.000	852.340	720,000
				1=2	743.360	720.000	720.000	720.000
				1=3	720.000	720.000	720.000	720.000
				1=4	720.000	720.000	720,000	720.000
				J=2,3				
				1=1	720.000	720.000	720.000	720.000
				1=2	720.000	720.000	720.000	720.000
				1=3	720.000	720.000	720.000	720.000
				1=4	720.000	720.000	720,000	720.000

Table V-8.—Input variables SP-2 —continued

Math symbol	Program symbol	Description	Unit	J=1	K=l	K=2	K=3	K–4
				J=1,2,3				
s'i]k	SWD	Producer supply with disposal of stockpile j	Million tons	1=1	0.750	0,750	U.750	0.750
				1=2	0.750	0.750	0.750	0.750
				1=3	0.750	0.750	0.750	0.750
				1=4	0.750	0.750	0.750	0.750
				J=l				
d'!i]k	DWD	Demand with disposal of stockpile	Million tons	1=1	1,500	1.500	1.458	0.000
				1=2	1.476	0.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0,000	0.000	0.000	0.000
				J=2				
				1=1	1.500	1.500	1.500	0.000
				1=2	1.500	0.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000
				J=3				
				1=1	1.500	1.500	1.500	0.000
				1=2	1.500	0.000	0.000	0.000
				1=3	0.000	0.000	0.000	0.000
				1=4	0.000	0.000	0.000	0.000

Table V–9.—Calculated results for SP-2

Economic impacts of stockpiling zinc [Millions of dollars]

‘Symbol .	Description	J=1	J = 2 [Millions of tons]	J=3 ,
		0.050	0.100	0.160
NBj	Net benefits	$26.2	30.3	–12.4
B	Benefits function	29.6	36.6	36.7
c	Cost function	3.4	6.3	48.9
E(DN)	Damage not averted	5.5	0.000	0.0
	Benefit variables:			
E(CS'j)	Expected consumer savings	78.8	95.8	95.8
E(PL'j)	Expected producer loss	56.3	68.7	68.7
E(Edj)	External damage	7.1	9.4	9.4
	Cost variables:			
HCj	Holding costs	2,9	5.8	9.519
	Initialization costs....	0.5	0.5	0.5
LEWj	Loss uneconomic welfare	0.0	0.0	38.9
CS.	Consumer loss	0.0	0.0	92.9
PG	Producer gain..	0.0	0.0	54.0
DCj	Disposal cost...	0.0	0.0	0.0
OCj	Operating costs	39.4	78.3	128.8
ACj	Acquisition costs	36.0	72.0	118.0
•*	Economic impact of no stockpile	29.6	36.7	36.6

“All calculations have been rounded for simplicity

**The economic impact of no stockpile is equivalent to the benefits (expected damages averted) attributed to the stockpile which are foregone in the absence of the stockpile.

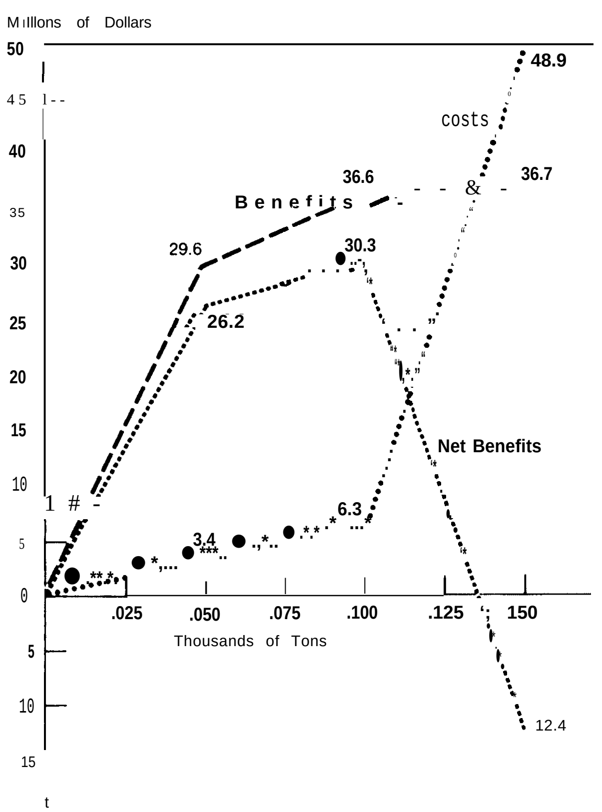
bol, the description of the variable, and the numerical value of the output variable for each stockpile, j.

d. Graphic Representation of the Calculations.—Figure V-6 is a graphic representation of the calculated costs, benefits, and net benefits (benefits minus costs) for SP–2, Values were computed for only three stockpile sizes and zero stockpile,

e. Optimal Stockpile Size.—The net benefit curve in figure V–6 can be used to indicate the probable optimal stockpile size, where the curve appears to be at a maximum positive value (or minimum negative value). This can only be taken as an indication of the area where the optimal size stockpile occurs; however, it will serve to illustrate the desired value of the stockpile size for the values of the input variables chosen.

Figure V 6.

Economic Net Benefits of SP-2



The calculations resulted in an optimal stockpile size in the area of 100,000 tons accumulated over a l-year period. The expected economic net benefits for this stockpile are estimated at $30 million. It should be emphasized that the estimates apply only to the specific materials examined and within the scenario assumptions described, and should therefore not be taken to indicate that precise quantities of specific materials should or should not be stockpiled. Nevertheless, the nature and magnitude of the estimates are sufficient to indicate that an economic stockpile should be given detailed consideration as one component of a more comprehensive national materials policy and that measuring the benefits or costs of a supply disruption in terms of the probability, rather than the certainty, of a disruption will significantly reduce the quantity of material to be stockpiled.

The U.S. stockpile of zinc in late 1974 was 373,000 short tons, while the stockpile objective is 203,000 short tons, The optimal stockpile range was based on the probability of our distinct possible interruptions and the damages that they would cause. The optimal stockpile is a minimum of 11 percent of the total annual imports of zinc.

The methodology illustrated by the example calculations for a zinc stockpile show that the stockpile size should be based upon the expected net benefits of the stockpile, The example calculations also show that a stockpile based upon the probability of an interruption is smaller than that required to offset every possible interruption in its entirety,

f. Sensitivity Analysis,—The computer program performs the "baseline" calculations and then automatically perturbs an input variable by +10 percent and reruns the calculations, The new costs, benefits, and net benefits are compared to the base calculations and the percentage change is computed. This process is repeated for each input variable.

The resulting percent changes in net benefits from a +10 percent change in each input variable for SP–2 are listed in table V–10,

Table V–10.—Percent change on 10 percent perturbation of variables SP–2

Perturbed variable	Benefits			cost			Net benefits		
	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3
CE	0.00	0.00	0.00	1.48	0.80	0.10	–0.19	–0.17	0.40
Cu	0.00	0.00	0.00	8.51	9.19	1.94	–1.10	–1.90	7.67
SV	0.00	0.00	0.00	.01	0.2	.00	.00	.00	.01
PROB	10.00	10.00	10.00	0.00	0.00	0.00	11.29	12.07	–29.52
PP	0.00	0.00	0.00	1595.27	861.24	87.49	–206.06	–178.23	345.79
D	0.00	0.00	0.00	0.00	0.00	11.03	0.00	0.00	43.60
s	0.00	0.00	0.00	0.00	0.00	–5.52	0.00	0.00	–21.80
DWD	.11	.09	.09	0.00	0.00	0.00	.12	.10	– .25
SWD	–.05	–.04	–.04	0.00	0.00	0.00	–.06	–0,5	.13
EDP	2.40	2.57	2.57	0.00	0.00	0.00	2.71	3.11	–7.60

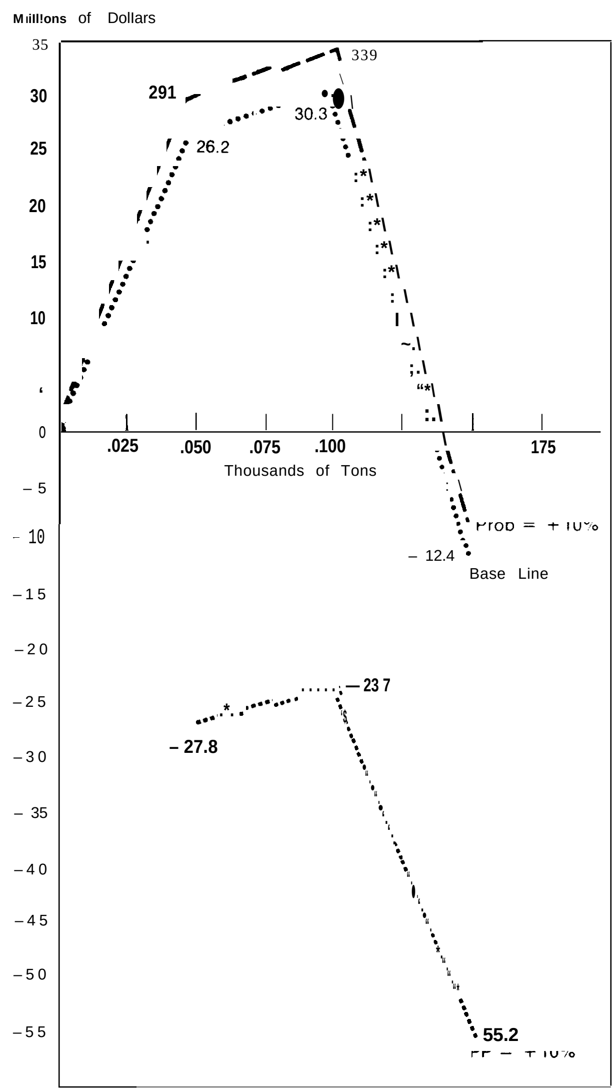
An examination of table V–10 shows the net benefits to be fairly insensitive to any input variable perturbation except for PP, increased price, While the net benefits for the baseline case show a peak in the range of 80,000 to 100,000 tons, this analysis shows that a IO-percent increase in price will result in a negative net benefit for this economic stockpile. This result is dramatically illustrated in Figure V–7.

3. Discussion of Partial Benefits and Costs for Each Phase of Stockpile Operation for SP–2

The above presentation of economic net benefits is supplemented by a discussion of the four categories of impacts. The economic impacts of a stockpile for SP–2 can be determined with the Economic Welfare Model for four types of impacts: direct benefits and costs to materials producers, direct benefits and costs to materials consumers, benefits and costs borne by the stockpile operator, and external benefits and costs. Calculations have been made to estimate each of these four types of economic impacts.

Figure V-7.

Perturbations of SP-2



a. Direct Benefits and Costs to Materials Producers.—The direct benefits and costs to materials producers of a zinc stockpile under SP–2 are summarized below:

Benefits and costs to producers		Stockpile size (Millions of tons)		
Operational action	Type of benefit or cost	0.1	0.1	0.2
Acquisition	Producer gain (PG_j)	0.0	0.0	54.0
Holding	Producer savings/loss	0.0	0.0	0.0
Disposal	Producer loss E (pL'_{ijk})*	56.3	68.7	68.7

● This term is expressed as an expected value (E).

b. Direct Benefits and Costs to Materials Consumers.—Direct benefits and costs to materials consumers of zinc as a result of a zinc stockpile under SP–2 are summarized below:

Benefits and costs to consumers		Stockpile size (Millions of tons)		
Operational action	Type of benefit or cost	0.1	0.1	0.2
Acquisition	Loss in consumer surplus (CLj)	0.0	0.0	92.9
Holding	Consumer savings/loss	0.0	0.0	0.0
Disposal	Consumer savings E (Cs'_{ijk})"	78.8	95.8	95.8

● This term is expressed as an expected value (E).

c. **Costs** and Benefits to the Stockpile Operator. -Costs and benefits to the stockpile operator for zinc stockpile under SP–2 are summarized below:

Revenues and costs to stockpile operators		Stockpile size (Millions of tons)		
Operatoinal action	Type of benefit or cost	0.1	0.1	0.2
Acquisition	Initialization cost (IC)	0.5	0.5	0.5
Holding	Holding cost (HC)	2.9	5.8	9.5
Disposal	Disposal cost (DC)	0.0	0.0	0.0
	Capital gains (CG)	0.0	0.0	0.0

d. **Estimation** of External Costs and Damages.—Estimation of external costs and damages can be done in a generalized first-order approximation, or it can be rigorously determined. The illustrative calculations. for a zinc stockpile under SP–2 utilize the first approach, a general approximation. The resulting external benefits and costs as given in the petroleum example are summarized below:

External costs and damages ,		Stockpile size (Millions of tons)		
Operational action	Type of benefit or cost	0.1	0.1	0.2
Acquisition	External cost (EC)	0.0	0.0	0.0
Holding	External damage (ED)	0.0	0.0	0.0
Disposal	External damage (ED')*	7.1	9.4	9.4

● The External Damage is the expected external damage (E).

Therefore:

$$ED'_j = \sum_i \sum_k P'_{ijk} ED'_{ijk} \qquad (18)$$

4. Summary of Economic Net Benefits and Partial Benefits for SP–2

The results of the calculations for SP–2 are summarized in table V-11, These results are for the initial year of operation and include heavy operating costs for acquisition and substantial impacts on producer and consumers associated with acquisition. During disposal, large savings accrue to consumers, while producers incur substantial losses. For comparison, table V–12 shows the terms in the net benefit function for the second year under the assumption that the prices, elasticities, and probabilities are the same. The costs to the stockpile operator fall significantly. The gains and losses to producers and consumers during acquisition and disposal are the same as in year 1. Expected net benefits are lower since they are expressed in present value terms, using a discount rate of 8 percent. For the second year, the optimal stockpile size remains in the area of 100,000 tons. In practice, the stockpile operation would periodically reassess probabilities and other data and recalculate net benefits. The results might indicate that the stockpile size should be increased or decreased with attendant economic impacts,

The cost to the Government of establishing a 100,000-ton stockpile is estimated to be about $78 million in the first year, with the major components being $72 million for purchase of zinc plus $0.5 million for purchase of storage and other facilities. In each succeeding year the cost of operation would be about $5.7 million if the stockpile size remained unchanged.

Table V-11.—Partial economic benefits and costs of SP–2 for first year of operation

(In Millions of dollars)

Type of benefit or cost	Size of stockpile millions of tons	Operational action*		
		Acquisition	Holding**	Disposal**
		PG_j	$E(PL_j)$	$E(PL'_j)$
Producers.	0.050	0.0	-0.0	–56.3
	0.100	0.0	-0.0	-68.7
	0.150	54.0	-0.0	-68.7
		CL_j	$E(CS_j)$	$E(CS'_j)$
Consumers.	0.050	-0.0	0.0	78.8
	0.100	-0.0	0.0	95.8
	0.150	-92.9	0.0	95.8
		IC_j	HC_j	(DC+CG)
Stockpile operators	0.050	-0.5	-2.9	-0.0
	0.100	-0.5	–5.8	-0.0
	0.150	-0.5	-9.5	-0.0
		EC	$E(ED_j)$	$E(ED'_j)$
External costs.	0.050	-0.0	0.0	7.1
	0.100	-0.0	0.0	9.4
	0.150	-0.0	0.0	9.4

Economic net benefits are 26.8 millions, 31.4 millions, and –11.2 millions for 0.050, 0.100, and 0.150 million tons of stockpile, respectively.

"Signs Indicate the sign which each term should have when summing to indicaty net benefits

● "Values in these columns are expected values ie they have been weighted by probabilities

Estimated economic net benefits and operating costs for three sizes of zinc stockpile for SP–2 under assumed conditions described in the text. Results are for the second year (or later years) and are illustrative only.

Table V–12.—Partial benefits and costs of SP–2 for second year of operation

(In Millions of dollars)

Type of benefit or cost	Size of stockpile millions of tons	Operational action*	
		Holding**	Disposal**
		$E(PL_j)$	$E(PL'_j)$
Producers	0.050	-0.0	–56.3
	0.100	-0.0	48.7
	0.150	4.0	-68.7
		$E(CS_j)$	$E(CS'_j)$
Consumers	0.050	0.0	78.8
	0.100	0.0	95.8
	0.150	0.0	95.8
		HC_j	(DC_j-CG_j)
Operators	0.050	–2.4	-0.0
	0.100	–5.8	-0.0
	0.150	4.5	4.0
		$E(ED_j)$	$E(ED'_j)$
External , ..., , ...	0.050	0.0	7.1
	0.150	0.0	9.4
	0.150	0.0	9.4

The present value of economic net benefits are 23.0 millions, and –9.6 millions for 0.050, 0.100, and 0.150 million tons of stockpile, respectively

*Signs indicate the sign which each term should have when summing to indicate net benefits

"*Values in these columns are expected values. ie . they halve been weighted by probability

D. ECONOMIC IMPACTS OF STOCKPILING TO ASSIST IN INTERNATIONAL MATERIALS MARKET STABILIZATION (SP-3)

The procedure for calculating the benefits of SP–3 is discussed immediately below, and the calculations of the net benefits are presented thereafter. The cost function for SP–3 has been described in the section in chapter IV on the Economic Welfare Model, equation **(7),**

1. Derivation of Benefit Function for SP-3

The benefits derived from SP–3 over the coming time period depend upon the degree of stabilization obtained in the international market and the effect upon the U.S. domestic market that such stabilization will produce. Four types of benefits result from the impact of this stockpile upon the domestic economy: an increase in domestic consumer-producer surplus, a decrease in production costs, a reduction in the external costs associated with instability, and the realization of capital gains. A fifth type of benefit is gained as a result of international market stabilization: political benefits that result from the United States entering commodity agreements with other countries.

The benefits from a stockpile of a given size over the entire surplus-shortage cycle should be estimated to calculate the benefit function of this type of stockpile over the coming time period. Since these benefits are derived over the entire surplus-shortage cycle, only a portion of these benefits should be credited to the coming time period, This portion (t) is defined as the ratio of the length of the coming period to the expected length of the surplus-shortage cycle. Thus, the benefits associated with a stockpile of size Q_j can be calculated by:

$$B_j = t(CS_j + PS_j + ED_j + CG_j + PBj) \quad (17)$$

where

B_j = Benefits expected for stockpile Q_j

t = Portion of surplus-shortage cycle occurring in the coming time period

CS_j = Increase in consumer-producer surplus

PS_j = Decrease in average production costs

ED_j = External damage, external costs saved

CG_j = Capital gains

PB_j = Political benefits

It is important to note, however, that the benefits to be measured for this policy are only those captured by the U.S. economy, with these benefits most likely being a small share of the aggregate benefits enjoyed by all participating countries.

The domestic increase in consumer-producer surplus over the surplus-shortage cycle can be estimated using the following procedure. Let ph be the highest price and pi the lowest price over the surplus-shortage cycle in the absence of stockpiling, as illustrated in figure V-8. Then p'_h and p'_i are the high and low prices at which all the material is sold when stockpiling takes place. If over the cycle all of the material were sold at p'_h and in the absence of stockpiling all material would have been sold at p_h, the increase in consumer surplus for the United States would be equal in figure V-8 to the trapezoid phcdp'h. and the loss in producer surplus (assuming there are U.S. producers) would be equal to the trapezoid phabph. Of course, in practice the price would vary over the range pi to ph in the absence of a stockpile and over the range pi to ph with a stockpile, so the increase in consumer surplus and the decrease in producer surplus would be only some fraction of the above amounts. Specifically, these amounts should be multiplied by the coefficient h, which reflects the proportion of total output over the cycle whose price would be higher than p'_h without a stockpile, and the coefficient g, which reduces the estimates of consumer gain and producer loss to account for the fact that

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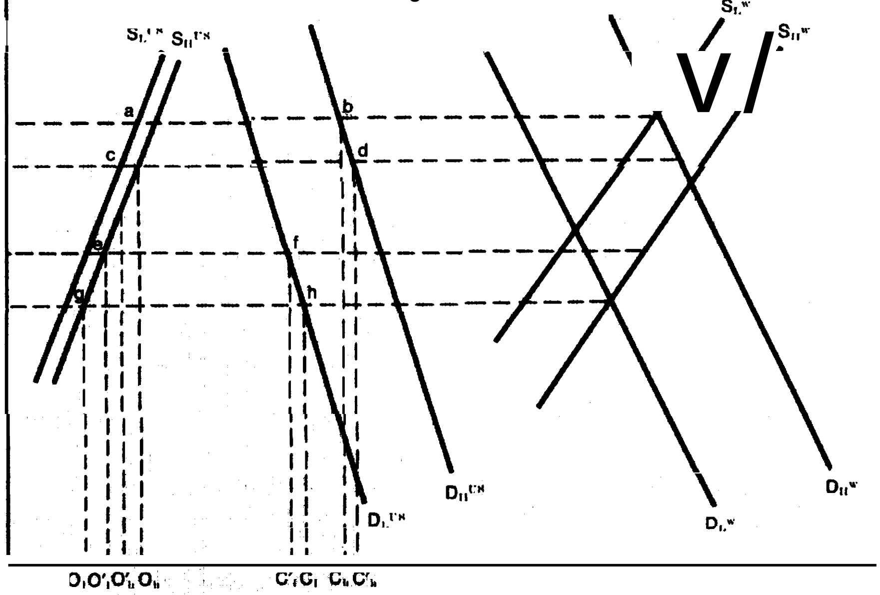
Figure V-8.



TERMS:

- S_L^{w} = low world supply
- S_H^{w} = high world supply
- D_L^{w} = low world demand
- D_H^{w} = high world demand
- P_h = high price without stockpiling
- P'_h = high price with stockpiling
- P_l = low price without stockpiling
- P'_l = low price with stockpiling
- S_L^{US} = low U.S. supply
- S_H^{US} = high U.S. supply
- D_L^{US} = low U.S. demand
- D_H^{US} = high U.S. demand
- O_l = U.S. output at P_l
- O'_l = U.S. output at P'_l
- O_h = U.S. output at P_h
- O'_h = U.S. output at P'_h
- C_l = U.S. consumption at P_l
- C'_l = U.S. consumption at P'_l
- C_h = U.S. consumption at P_h
- C'_h = U.S. consumption at P'_h

in the absence of a stockpile the price which would prevail above p'h would vary over the range p'h to p_h and would not be continually maintained at p_h.

Similarly, during the accumulation phase of a stockpile program, the decrease in consumer surplus and increase in producer surplus can be estimated by multiplying the trapezoids p'hghpl and p'iefpi times the coefficient g and the coefficient m, where the latter is the proportion of total output over the cycle whose price would be lower than P'_i without a stockpile.

Thus, the net gain in consumer-producer surplus over the cycle can be estimated by the following equation on the assumption that the U.S. supply and demand curves are approximately linear over the price ranges $p_h - p_h$ and $p'_l - p_l$:

$$CS_j = hg(P_h - P'_h)\ [C_h + 1/2(C'_h - C_h) - O'_h - 1/2(O_h - O'_h)] + mg(P'_e - P_e)\ [O_l + 1/2(O'_l - O_l) - C'_l - 1/2(C_l - C'_l)] \quad (18)$$

The external damage can be estimated as the reduction in external cost attributable to stockpiling. The estimates of these benefits may be made through judgmental estimates of the stabilizing impact of the stockpile to the total domestic economy. Capital gains (losses) must be added to the benefit function. They are defined in equation (19) as:

(19)

where

P_l = Price at which Q_j is acquired
ph = Price at which Q_j is Sold
Q^*_j = quantity of stocks accumulated and disposed of over the cycle

Significant capital gains may be realized from this stockpiling policy. While making a financial profit is not the objective of SP–5, the accrual of capital gains will be an additional benefit.

The reduction in production costs that greater cyclical stability produces can be estimated by those familiar with the production technology and past production behavior of materials. The total reduction will depend on the quantity produced as well as the reduction in the average cost of production, as shown in equation (20):

$$PS_j = cp_j s_a \qquad (20)$$

where

PS_j = decrease in production costs resulting from stockpile j
cp_j = unit cost of production saved by stabilization due to stockpiling
s_a = domestic production of material over the entire cycle

The cost function for SP–5 varies slightly from the general cost function (equation 7 in chapter IV) in that it does not incorporate values for loss in domestic consumer surplus (LCS_j) or external cost (EC_j) when the acquisition of the stockpile occurs during the surplus portion of the surplus-shortage cycle. These factors are included in the benefit function as negative benefits during the surplus portion of the cycle as it normally occurs. However, if the initiation of stockpile acquisition does not occur at the beginning of the surplus cycle, the quantity required by the stockpile to alleviate the shortage portion of the cycle would have to be accumulated over a shorter time period than planned, An accelerated acquisition of the stockpile increases both the loss of consumer surplus and external costs,

The political benefits (PB) derived by the United States from participating in an international stockpiling program must be estimated in order to determine the total benefits. The value of political benefits is normative and will be dependent upon such factors as the importance of the material internationally, the countries affected by the stabilization of fluctuations (both producers and consumers), and the prestige attributed to the United States by its leadership in promoting the commodity agreement. These political benefits are expressed as PB_j in equation (17).

Even though the political benefits variable is a normative value, its reasonableness can still be determined. For example, the economic net benefits can be estimated for an international stockpile by setting the political benefits equal to zero. If, in considering a fixed U.S. share of the stockpiling costs, the net benefits for the stockpile are negative, the political benefit variable can be increased to the point where net benefits are positive. This new value can then be examined for its reasonableness in light of the international environment.

The cost function for SP–5 will not have values for loss in domestic consumer surplus LCS_j or external costs (EC_j) when the acquisition of the stockpile occurs during the entire surplus portion of the surplus-shortage cycle. These factors are included in the benefit function as negative benefits during the surplus portion of the cycle as it normally occurs. However, if the initiation of stockpile acquisition does not occur at the beginning of the surplus cycle, the quantity required by the stockpile to alleviate the shortage portion of the cycle would have to be accumulated over a shorter time period than planned, resulting in a greater loss of consumer surplus and increased external costs.

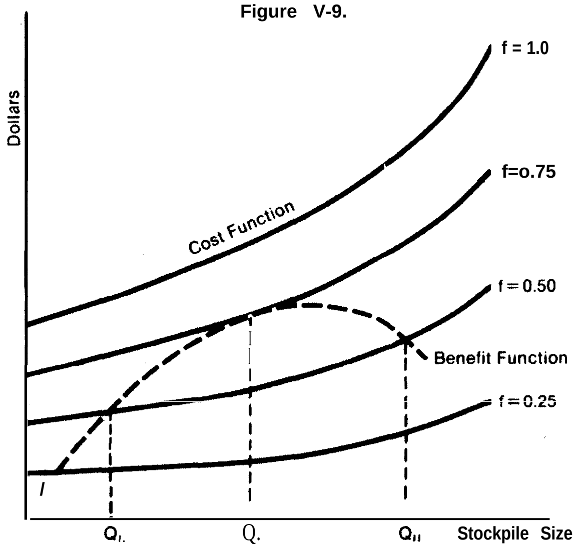
As equation (7) indicates, the remaining terms in the cost equation, aside from the fixed initialization cost (C F), are functions of stockpile size. The cost of the international stockpile is based upon the total stockpile size, only part of which need be borne by the United States. International commodity agreements such as the International" Energy Program (IEP) will establish procedures for sharing the burdens of materials shortages and surpluses. Therefore, only a portion of the total cost of stockpiling will be an obligation of the United States, as given by equation (21):

(21)

where
- Cj = cost of stockpile j
- f = fraction of stockpile costs for which United States is obligated
- C'_j = cost of stockpile j for which United States is obligated

The net benefits for SP–3 are calculated for each stockpile size, Q", from the benefits determined in equation (17) and the costs from equation (21). The calculations described above should be repeated for stockpiles of various sizes to trace out the entire benefit function, The cost function can be calculated for various size stockpiles and for varying values of f as shown in figure V– 9.

Figure V-9.



TERMS:
f = fraction—U.S. share of stockpile costs
Q, = low stockpile size where net benefits are positive for f =0.50
Q,, = high stockpile size where net benefits are positive for f =0.50
Q. = optimal stockpile size for f = 0.50

The family of cost curves shown in figure V–9 can be used to determine the "critical" value of f (i. e., the maximum fraction of cost incurred by the United States which will insure that net benefits to the United States are positive). The "critical" f occurs for that curve in the family of cost curves tangent to the U.S. benefit function curve. If one wished to determine the optimal stockpile size for a given f, then the slope of that cost function would be equal to the slope of the benefit function.

2. Estimation of Economic Net Benefits for SP–3

Tin has been selected as the material for the application of the Economic Welfare Model to SP–3, World resources of tin are located primarily in Southeast Asia, Bolivia, Brazil, Nigeria, China, U. S. S.R., and Zaire, U.S. imports of tin are mainly from Malaysia (62 percent) and Thailand (25 percent). Between 1966 and 1972, the price of tin on the London Metal Exchange fluctuated between $1,296 and $1,506 per ton. This fluctuation is expected to continue.

a. Background Information.—The important values and assumptions employed in this calculation are summarized here:

- Future prices are assumed to be equal to the prices occurring during the last 6-year cycle. Under this assumption the high, low, and average prices in dollars per ton are respectively $8,250, $7,227, and $7,739.
- The reduction in average production cost due to reduced price fluctuation is set at zero, since U.S. production of tin is negligible.
- Increases and decreases in producer surplus are assumed to be zero since U.S. tin production is negligible.
- External damage averted is again measured in terms of the value of unemployment benefits saved, Savings are estimated below:

	Stockpile size (in tons)		
	J=l	J=2	J=3
	5,000	10,OOO	20,000
Unemployment benefits saved ($ millions)	0.062	0.124	0.124

- The political benefit variable is set at zero. Later, in the "political tradeoff analysis," the value of this variable required to make the net benefits for the United States just equal to zero is calculated.

The coefficient f (fraction of costs incurred by the United States) is initiallv set at 1 and then adjusted under alternative assumptions.'

b. Input Values.—The values for the input variables to the computer program for SP–3 are listed in table V–13, This table lists the mathematical symbol, the name or description of the variable, the units of measure, and the numerical value of the input variable for each I, J, and K. The calculations for the SP–3 were

Table V-13.—Input variables SP–3

Math symbol	Program symbol	Description	Units	Dependent Either/ on J, or J=l	J=2	J=3
Qj		Stockpile size	Million ton	0.005	0.01	0.02
Q_j	QS	Stockpile accumulations and disposals	Million ton	0.005	0.006	0.006
Cu	Cu	Unit cost	$ per ton	7588.0	7700.0	7700.0
C_f	CF	Fixed initialization cost	Million $	0.5		
c "	CV	Variable initialization cost	$ per ton	0.0		
i	XI	Interest rate	Percent per year	0.08		
d	SLR	Spoilage loss rate	Percent per year	0.0		
s	SC	Storage cost	$ per ton per year	0.29		
t	T	Portion of surplus-shortage cycle occurring in the coming time period	Million tons	0.166866		
c_{p_i}	CP	Unit cost of domestic production saved by stabilizing due to stockpiling	$ per ton per year	0.0	0.0	0.0
'a	SA	Domestic production of material over the entire cycle	Million tons	0.0		
g	G	Fraction reflecting distribution of prices	Coefficient	0.5		
p_h	PH	High price without stockpiling	$ per ton	8250.0		
p'_h	PHP	High price with disposal of stockpile j	$ per ton	7838.0	7778.0	7778.0
p_l	PM	Low price without stockpile	$ per ton	7227.0		
p'_l	PMP	Low price with acquisition of stockpile j	$ per ton	7588.0	7700.0	7700,0
C_h	CH	High U.S. consumption without stockpile over cycle	Million tons	0.336378	0.342151	0.342151
c'_h	CHP	High U.S. consumption with stockpile over cycle	Million tons	0.341418	0.342151	0.342151
c_l	CL	Low U.S. consumption without stockpile over cycle	Million tons	0.328740		
c'_l	CLP	Low U.S. consumption with stockpile over cycle	Million tons	0.323814	0.322285	0.322285
PB	PB	Political benefits of stockpiling	Million $	0.0		
f	F	Fraction of stockpile costs obligated to by U.S.	Coefficient	1.0		
ED_{ik}	ED	External damage-no stockpile	Million $	0.062	0.124	0.124
m	M	Fraction of total output over the cycle whose price would be lower than p'_l without a stockpile	Coefficient	.38	.5	.5
h	H	Fraction of total output over the cycle whose price would be higher than p'_h without a stockpile	Coefficient	.38	.5	.5

performed by computer program for the input variables listed in table V-13.

c. Calculated (Output) Values.—The values for the output variables calculated by the computer program for SP–5 are listed in table V–14. This table lists the mathematical symbol, the description of the variable, the units of measure, and the numerical value of the output variable for each stockpile j

d. Graphic Representation of the Calculations.—Figure V-10 is a graphic representation of the calculated costs, benefits, and net benefits (benefits minus costs) for SP–3. Values are computed for only the known three chosen stockpile sizes and zero stockpile.

e. Optimal Stockpile Size.—The net benefit curve in figure V-10 can be used to indicate the probable optimal stockpile size, where the curve appears to be at a maximum positive value (or minimum negative value). This can only be taken as an indication of the

Figure V 10.
Economic Net Benefits of SP-3

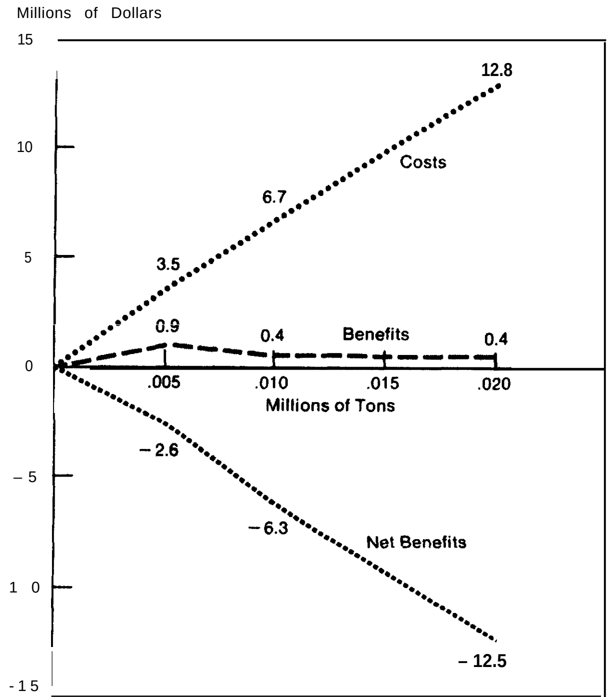


Table V–l4.—Calculated results for SP-3

Economic impacts of stockpiling tin
[Millions of dollars]

symbol	Description	J=1	J=2 (Millions of tons)	J=3
		.005	0.10	0.20
NB_j	Net benefits	–2.6	–6.3	–12.5
B	Benefits function	0.9	0.4	0.4
C_j	Cost function	3.5	6.7	12.8
DN*	Damage not averted			
	Benefit variables:			
CS_j	Increase in consumer surplus	4.2	1.5	1.5
PROD ST_j	Production costs saved	0.0	0.0	0.0
CG_j	Capital gains	1.3	0.5	0.5
ED_j	External damage	0.1	0.1	0.1
	Cost variables:			
CjF	Cost obligated to United States	3.5	6.7	12.8
HC_j	Holding costs	3.0	6.2	12.3
IC_j	Initialization costs	0.5	0.5	0.5
DC_j	Disposal costs	0.0	0.0	0.0
OC_j	Operating costs	40.2	83.2	166.4
AC_j	Acquisition costs	37.9	77.0	154.0
	Economic impact of no stockpile	0.9	0.4	0.4

● Damage not averted for SP–3 has not been calculated for reasons described on page
Note: All calculations have been rounded off for simplicity

area where the optimal size occurs; however, it will serve to illustrate the desired value of the stockpile size for the values of the input variables chosen, It should be noted that the benefits (increase in consumer surplus and external damage averted) for stockpile size Q_2 and Q_3 are the same. The reason for this is that full price stabilization-defined as 1 percent fluctuation— is accomplished with a stockpile size equal to about 6,000.

It should be emphasized that the estimates apply only to the specific materials examined *and with in the scenario assumptions* described, and should therefore not be taken to indicate that precise quantities of specific materials should *or* should not *be* stockpiled. Nevertheless, the nature and magnitude of the estimates are sufficient to indicate that an economic stockpile should be given detailed consideration as one component of a more comprehensive national materials policy and that measuring the benefits or costs of a supply disruption in terms of the probability, rather than the certainty, of a disruption will significantly reduce the quantity of material to be stockpiled,

Net benefits are negative for all three stockpile sizes. There are, however, several important factors which have not yet been discussed and which could change the net benefit estimates. First, net benefits could be positive for a stockpile size which is less than 5,000 tons; costs and benefits for smaller stockpile sizes have not been computed in this illustration. Second, it will be recalled that the coefficient f was set at 1.0 which assumes that the United States bears the full cost of the international tin stockpile. Under a more realistic value for f of 0.25, net benefits to the United States increase substantially, resulting in positive net benefits of $0,026 million for J_1. Finally, the base case illustration assumed the political benefits variable (PB) to be zero. For J]—retaining f at I, O-the PB variable would have to be **$2.63** million before net benefits became positive.

As a measure of scale for the results of these calculations, the proposed actions of the 1nternational Tin Council can be considered. Presently, the ITC maintains a stockpile of approximately 20,000 tons. The ITC is contemplating an increase of this buffer stock to 40,000 tons. The U.S. stockpile (as of Nov. 30, 1974) had 207,478 tons of pig tin, while the objective for the stockpile is 40,500 tons of pig tin.

Assuming that the ITC proposes an incremental stockpile of 20,000 tons and that the benefits to the United States and the total stockpile costs are as shown in table V–14, it would be useful to determine the critical values of f and PB under which U.S. participation would be justified. Maintaining PB equal to zero, the fraction of U.S. participation would be only 2,8 percent, or 560 tons. Alternatively, if the U.S. share were set at a more realistic level, say, 10 percent or 2,000 tons, the political benefits (PB) would have to equal or exceed $0.927 million for the net benefits of participation to be positive for the United States. These example calculations demonstrate the utility of the Economic Welfare Model—and particularly the political benefits variable and the U.S. cost fraction—in assessing U.S. participation in an international stockpile.

f. Sensitivity analysis for SP–5. -The computer program performs the “baseline” calculations and then automatically perturbs an input variable by +10 percent and reruns the calculations, The new costs, benefits, and net benefits are compared to the baseline calculations and the percentage change is computed. This process is repeated for each input variable.

The resulting percent changes in net benefits from a +10-percent change in each input variable for SP-3 are listed in table V–15.

An examination of table V–15 shows that the net benefits for SP–5 are fairly sensitive to changes in most of the input variables with the maximum changes occurring with a perturbation of (a) high price without stockpiling (PH) and *(b)* low price with disposal of stockpile (PMP).

Table V–15.—Percent change on 10 percent perturbation of variables of SP–3

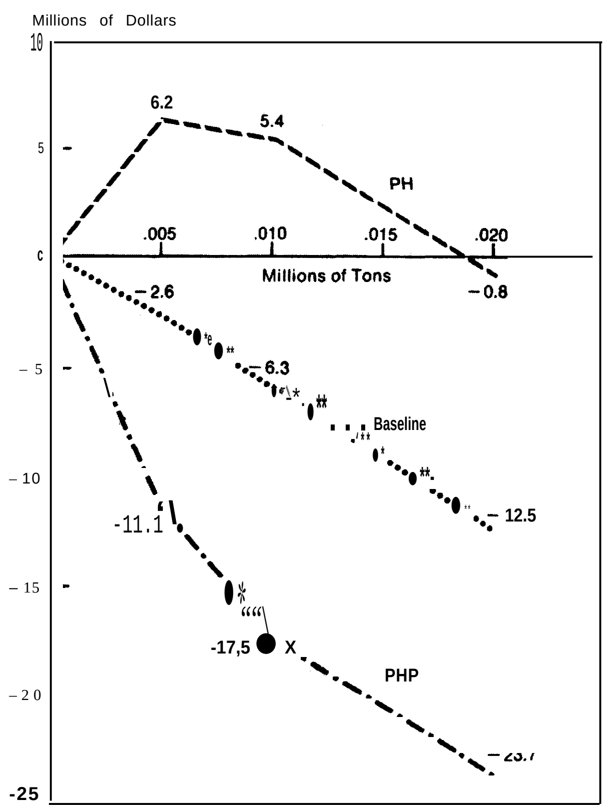
Perturbed variables	Benefits			cost			Net Benefits		
	Q1	Q2	Q3	QI	Q2	Q3	Q1	Q2	Q3
CF	0.00	0.00	0.00	1.41	0.75	0.39	1.90	0.79	0.40
Cu	0.00	0.00	0.00	8.58	9.25	9.61	11.56	9.77	9.86
SC	0.00	0.00	0.00	0.00	0.00	0.00	0.1	0.00	0.00
ED	0.11	0.56	0.58	0.00	0.00	0.00	–0.04	–0.03	–0.02
T	10.00	10.00	10.00	0.00	0.00	0.00	–3.47	–0.56	–0.29
G	7.60	7.23	7.23	0.00	0.00	0.00	–2.63	–0.41	–0.21
PH	972.65	3279.97	3279.97	0.00	0.00	0.00	–337.11	–184.90	–93.52
PHP	–852.32	–2873.56	–2873.56	0.00	0.00	0.00	295.40	161.99	81.93
PM	820.31	2756.79	2756.79	0.00	0.00	0.00	–264.31	–155.41	-76.60
PMP	–930.76	–3153.78	–3153.78	0.00	0.00	0.00	322.59	177.79	89.92
CH	24.11	93.03	93.03	0.00	0.00	0.00	–8.35	–5.24	–2.65
CHP	24.47	94.63	94.63	0.00	0.00	0.00	–8.48	–5.33	–2.70
CL	–20.64	–91.11	–91.11	0.00	0.00	0.00	7.15	5.14	2.60
CLP	–20.33	–69.32	–89.32	0.00	0.00	0.00	7.05	5.04	2.55
QS	2.28	2.19	2.19	0.00	0.00	0.00	–0.79	–0.12	–0.06
XI	0.00	0.00	0.00	8.58	9.25	9.61	11.56	9.77	9.88
M	–40.96	–160.43	–180.43	0.00	0.00	0.00	14.20	10.17	5.14
H	48.57	187.65	187.65	0.00	0.00	0.00	–16.83	–10.58	–5.35

The net benefit functions for the baseline and the extreme perturbation cases are plotted in figure V-11. The conclusions will change to an optimum stockpile size of about 5.000 tons if PH increases by +10 percent.

3. Discussion of Partial Benefits and Costs for Each Phase of Stockpile Operation for SP-3

The above presentation of net benefits can be supplemented by a discussion of how the total is made up of the categories of impacts. The economic impacts of a tin stockpile for SP–3 can be determined with the Economic Welfare Model for three types of impacts: direct benefits and costs to materials consumers, benefits and costs borne by the stockpile investor, and external benefits and costs. Calculations have been made to estimate each of these three types of economic impacts. The costs and benefits shown below by phase of stockpile operation are those expected for the coming time period (i.e., a year) rather than over the full 6-year cycle.

Figure V-1 1.
Perturbations for SP-3



a. The Direct Benefits and Costs to Materials Consumers.—The direct benefits and costs to materials consumers of tin as a result of a tin economic stockpile under SP–3 are summarized below:

Benefits and costs to consumers		Stockpile size (Millions of tons)		
		(Millions of dollars)		
Operational action	Type of benefit or cost	0.005	0.010	0.020
Acquisition	Consumer loss (CL)	–3.7	–6.4	–6.4
Holding	Consumer loss (CL')	.000	.000	.000
Disposal	Consumer Savings (CS)	4.4	6.7	6.7

b. The Costs and Benefits to the Stockpile Investor.—The costs and benefits to the stockpile investor for an economic stockpile of tin under SP–3 are summarized below:

Revenues ● nd costs to stockpile operators		Stockpile size (Millions of tons)		
		(Millions of dollars)		
Operational ● ction	Type of benefit or cost	0.005	0.010	0.020
Acquisition	Initialization cost (IC)	0.5	0.5	0.5
Holding	Holding cost (HC)	3.0	6.2	12.3
Disposal	Disposal cost (DC)	0.0	0.0	0.0
	Capital gains (CG)	0.2	0.1	0.1

c. The Estimation of External Costs and Damages.—The estimation of external costs and damages can be done in a generalized, first-order approximation, or it can be rigorously determined. No external costs and benefits were estimated for SP–3. The illustrative calculations for a tin stockpile under SP–3 utilize the first approach, a general approximation. The resulting external benefits and costs as given in the tin example are summarized below:

External costs and damages		Stockpile size (Millions of tons)		
		(Millions of dollars)		
Operational action	Type of benefit or cost	0.005	0.010	0.020
Acquisition	External cost (EC)	0.0	0.0	0.0
Holding	External damage E(ED)*	0.0	0.0	0.0
Disposal	External damage E(ED')*	0.0	0.0	0.0

*Benefits are allocated evenly to the acquisition and disposal stages

4. Summary of Economic Net Benefits and Partial Benefits for SP-3

The results of the calculations for SP-3 are summarized for years one and two in tables V–16 and V–17, respectively. It is assumed that the expected benefits and costs of stockpiling are the same for each year, though the present value of these benefits and costs will differ. As discussed previously, the net benefits of an international tin stockpile are negative for all three specified stockpile sizes when the value of f is set equal to 1 and the value of PB to zero. Changes in the values of f and PB, however, may yield positive net benefits.

For a complete discussion of the Operating Cost Model and estimates of the costs of implementing and running an economic stockpile, refer to the section in chapter VI on Budget Cost Implications. The operating costs are indicated here for conceptual understanding, The cost to the Government of establishing a 5,000-ton" tin stockpile is estimated to be about $40 million in the first year, with the major components being $37.9 million for purchase of tin plus $0.500 million for purchase of storage and other facilities and $3.0 million for holding costs. Offsetting these costs are capital gains of $1.3 million. In each succeeding year the cost of operation would only be the holding costs minus the capital gains if the stockpile size remains unchanged.

The distribution effects of this particular stockpiling policy are not fully illustrated with the example material. For example, potential producer gains in the form of production cost savings have not been estimated. Materials consumers are modest gainers. The stockpile operator captures a capital gain, but it does not completely offset the economic costs of stockpiling. Costs not covered by capital gains are borne solely by the operator (taxpayer), which means that the distributive effects of the cost function cannot readily be estimated.

Table V–16.—Partial economic benefits and costs of SP–3 for first year of operation
in **millions of dollars**

Type of benefit or cost	Size of stockpile millions of tons	Operational action*		
		Acquisition	Holding	Disposal
Producers. ... , , ...	0.005	0.0	0.0	0.0
	0.010	0.0	0.0	0.0
	0,020	0.0	0.0	0.0
Consumers.	0.005	–3.7	0.0	4.4
	0.010	6.4	0.0	6.7
	0.020	6.4	0.0	6.7
Operators. ., ...	0.005	–0,6	–3.0	0.2
	0.010	–0.5	–6.2	0.1
	0,020	–0.5	–12.3	0.1
External.	0.005	0.0	0.0	0.0
	0.010	0.0	0.0	0.0
	0.020	0.0	0.0	0.0

Net benefits are $–2.6 millions, $-6.3 millions, and $–12.5 millions for 0.005, 0.010, and 0,020 million tons of stockpile, respectively.

"Signs indicate the sign which each term should have when summing to indicate net benefits

Table V–l7.—Partial economic benefits and costs of SP-5 for second year of operation
(In Millions of dollars)

Type of benefit or cost	Size of stockpile Millions of tons]	Operational action*		
		Acqiisition	Holding	Disposal
Producers, , ... , ...	0.005	0.0	0.0	0.0
	0.010	0.0	0.0	0.0
	0,020	0.0	0.0	0.0
Consumers.	0.005	–3.7	0.0	4.4
	0.010	–6.4	0.0	6.7
	0.020	–6.4	0.0	6.7
Operators. ... , ...	0.005	–0.5	–3.0	0.2
	0.010	–0.5	–6.2	0.1
	0.020	–0.5	–12.8	0.1
External. ., ...	0.005	0.0	0.0	0.0
	0.010	0.0	0.0	0.0
	0.020	0,0	0.0	0.0

The present vaIue of net benefits is –$2.4 millions, –$5.8 millions, and –$11.5 millions for 0.005, 0.010, and 0.020 million tons of stockpile, respectively, assuming a time discount rate of 8 percent.

*Signs indicate the sign which each term should have when summing to indicate net benefits.

E. ECONOMIC IMPACTS OF STOCKPILING TO CONSERVE SCARCE DOMESTIC MATERIALS (SP-4)

The benefits derived from SP-4 are a result of the modification of the production and consumption of a material over time from what normally would occur without a stockpile. The cost function has been described in the section in chapter IV on the Economic Welfare Model, equation (7). The only modification required for SP-4 is that holding costs are incurred over the full-time horizon, and thus must be discounted to present value and summed. The benefit function for SP-4 is developed in the subsequent paragraphs. Calculations of the net benefits are presented immediately thereafter.

1. Derivation of the Benefit Function for SP-4

The benefits derived from SP-4 address a stockpile designed to assure that the total available stock of scarce domestic materials is produced and consumed at a rate which differs from that achieved in a market without intervention. This type of stockpile would accumulate stocks now and dispose of them during a later time period. The acquisition of stocks increases prices in the current period, thus reducing consumption and stimulating production.

The reasons private stockpiling might fail to accumulate the optimal level of stocks to achieve the objectives of this stockpiling policy include: (1) the time horizon of firms in the private sector differs from the time horizon of society; (2) the social and private time rates of discount differ; (3) expectations held by the Government and the private sector regarding future scarcity and prices differ; (4) the social benefits associated with this type of stockpile cannot be entirely appropriated by private stockpilers because of price controls, taxes on capital gains, and other factors.

Accumulation of stocks in the coming time period t. will shift the domestic demand curve to the right as shown in figure V-l2a, The price rises from p_0 to p'_0 if stocks equal to q'_o minus q_0 are accumulated, This results in a loss of consumer surplus equal to the trapezoid p'_0dcp_0 and a gain in producer surplus equal to the trapezoid p'_0acp_0 for a net welfare gain equal to triangle dac. This net welfare gain can be derived from the following equations:

$$PG = (p'_0-p_0)q'_0 - 1/2(p'_0-p_0)(g'_0-q_0)0.5 \quad (22a)$$

where PG = Producer gain

$$CL = (p'_0-p_0)q'_0 - 1/2(p'_0-p_0)(q'_0-q_0)0.5 \quad (22b)$$

where CL= Consumer Loss

Net producer surplus (PG – CL) can be derived from the above equations as:

$$1/2(p'_0-p_0)q'_{0i} \quad (22C)$$

where q'_{oj} is the size of the stockpile accumulated in the current period.

Disposal of stocks in a future time period t_f will shift the supply curve to the right, causing a drop in the equilibrium price from p_t to p'_t as illustrated in figure V-12b. This produces an increase in consumer surplus equal to trapezoid $p_tefp'_t$ and a decrease in producer surplus of $p_tegp'_t$ for a net gain of efg. This net gain is derived from equations 22d, 22e, and 22f below,

$$CS = (p_t-p'_t)q'_t - 1/2(p_t-p'_t)(q'_t-q)0.5 \quad (22d)$$

$$PL = (p_t-p'_t)q'_t - 1/2(p_t-p'_t)(q'_t-q)0.5 \quad (22e)$$

Where net consumer surplus (CS – PL) is reduced to the equation:

$$1/2(p_t-p'_t)q'_{ti} \quad (22f)$$

Where q'_{tj} is the size of the stockpile disposed in the future time period.

Figure V-12a.

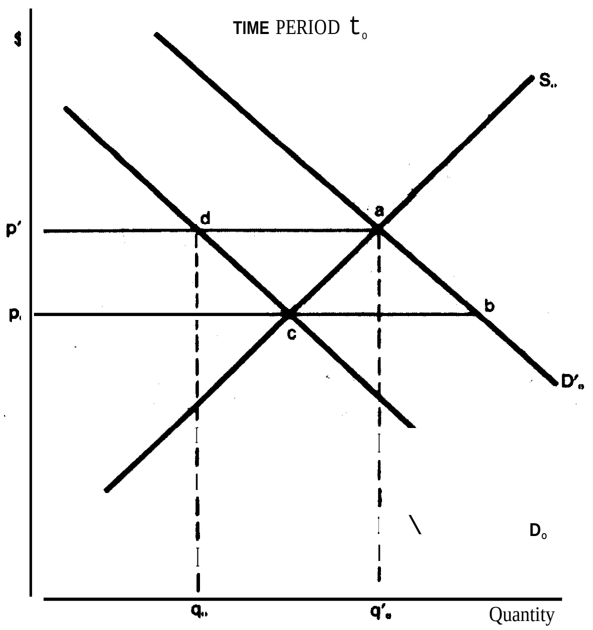
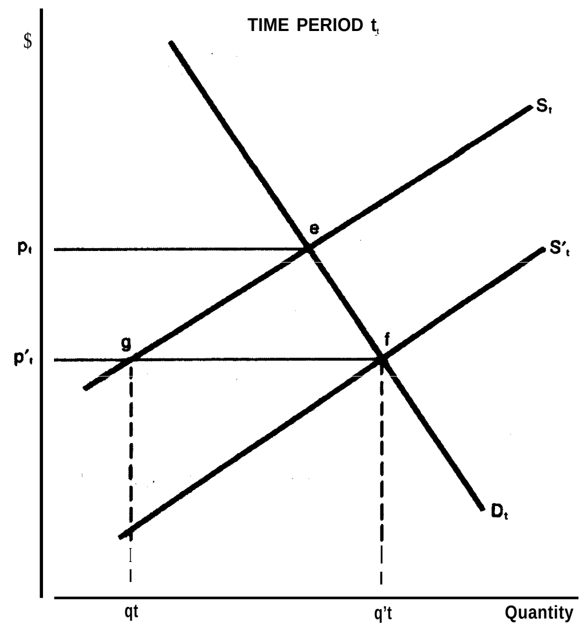


Figure V-12b.



TERMS:
p = price D = demand curve
q = quantities S = supply curve

External damage saved in the future time period t_f due to the disposal of the stockpile must be included in the benefit function, These damages averted will arise from the availability of the material and the increased output this availability will maintain, These external damages must be discounted to their present value as was the future net consumer surplus.

Before the total net benefit to society of saving material in a stockpile for some future time period can be determined, the capital gains (or losses) realized on the purchase and sale of the commodity must be added (subtracted) to the benefits, Since interest costs are included in the calculation of the total costs of stockpiling, the capital gain should not be discounted for time. This implies, however, that society's time rate of discount is the appropriate interest rate to use in the cost function so that the capital gains apply only to the quantity of material available for sale in the future time period (i.e., $q'_t - q_t$).

The benefits associated with stockpiling for SP–4 can be measured by the following equation:

$$B_j = [1/2(p'_{0j} - p_0)(Q_{0j}) + 1/2(p_t - p'_{tj})(Q_{tj})] \quad (1+i)^{-tf} + (p'_{tj} - p'_{0j})(Q_{tj}) + ED_{tj}(1+i)^{-tf} \qquad (23)$$

where

B_j = Benefits from stockpile j
PO = price in current time period without stockpile acquisition
P_t = price in future time period without stockpile disposal
i = discount rate
tf = time horizon; years between current time and future time
Q_{0j} = size of stockpile j accumulated in current time period
Q_{tj} = size of stockpile j disposed in future time period
P'_{0j} = price in current time period with acquisition
P'_{tj} = price in future time period with disposal
ED_{tj} = External damages saved in future time period with disposal of stockpile j

The first term or equation (23) is the net increase in producer surplus in the current time period, The second term in equation (23) is the net increase in consumer surplus in the future time period discounted to its present value. The third term is the capital gains (or losses) accrued in acquisition and disposal of the stockpile. The fourth term in equation (23) gives the external damages saved in the future time period discounted to its present value.

Under certain conditions, equation (23) could be modified to reflect more complex relationships of the current and future market. One condition would be if the present value of the price in the future time period is below the present value of the expected price in any other time period, t_{ftr}. In such situations, the benefits can be increased by releasing some of the stocks in the period t_{ftr} as well as in period t_f. The price reached by release of stocks in time period t_{ftr} should be reduced to the point that the price discounted with time equals the reduce price in time period t_f [i. e., $p'_t = p'_{t+r}$ (1+i) 4-r]. Equation (23) can be expanded with this method in order to allocate stockpile disposals over several future time periods.

The calculation of benefits and costs must be made for various stockpile sizes to trace out the entire benefit function and cost function for SP-4. The expected net benefits can then be determined for each stockpile size.

2. Estimation of Net Benefits for SP-4

Tungsten was selected as the material for application of the Economic Welfare Model to SP–4. While tungsten satisfies the materials selection criteria for SP-4, it would have been more consistent with the intent of this policy to use a material where domestic production accounts for the bulk of total supply. As it is, imports constitute a major portion of total tungsten supply. Nonetheless, this illustration is based upon that portion of total demand satisfied by domestic production. This assumes that the acquisition of tungsten in a stockpile for a future period will be used solely to stimulate domestic production, while its disposal will be used solely to reduce domestic supply shortages in the future.

a. Background In formation.—Other values and assumptions used in the analysis include the following:

- The time period under consideration is 1974 (the current period) to 1980 (the future period). The year 1980 is taken for ease of calculation. Normally, the time horizon of society under this policy would be on the order of 30, 40, or more years.
- Domestic supply and demand values and prices for 1974 and 1980 are presented in the table below. Growth rates of 7 percent and 2percent are postulated for demand and supply respectively.

	1 9 4	1980
Price ($/tons]	8,500	12,500
Demand (tons)	3,875	5,820
Supply (tons)	3,875	4,364

- The price elasticity of supply is estimated to fall in the range of 0.35 to 0.5 in the current period but to decline by 50 percent in the future period.
- The price elasticity of demand for tungsten is estimated to be in the area of -0.9 for both current and future periods.
- A discount rate of 8 percent has been used for computing future costs and benefits of stockpiling tungsten to their present value.
- External costs and damages averted for tungsten are estimated by using from SP–2 the ratio of GNP lost to the value of zinc imports interrupted (1.008), which in turn is applied to the value of tungsten acquired or forgone to derive losses of GNP. Implicit in this approach is that interindustry relationships of the two materials are the same. Admittedly, this approach to estimating external costs and damages averted can provide only an approximation to the actual values.

b. Input Values.—The values for the input variables to the computer program for SP-4 are listed in table V-18. This table lists the mathematical symbol, the name, or description, of the variable, the units of measure, and the numerical value of the input variable for each stockpile size. The calculations for the SP-4 were performed by computer program for the input variables listed in table V–18.

c. Calculated (Output) Values.—The values for the output variables calculated by the computer program for SP-4 are listed in table V–19. This table lists the mathematical symbol, the description of the variable, the units of measure, and the numerical value of the output variable for each stockpile j.

d. Graphic Representation of the Calculations.—Figure V-13 is a graphic representation of the calculated costs, benefits, and net benefits (benefits minus costs) for SP-4. Values are computed only for three stockpile sizes and zero stockpile,

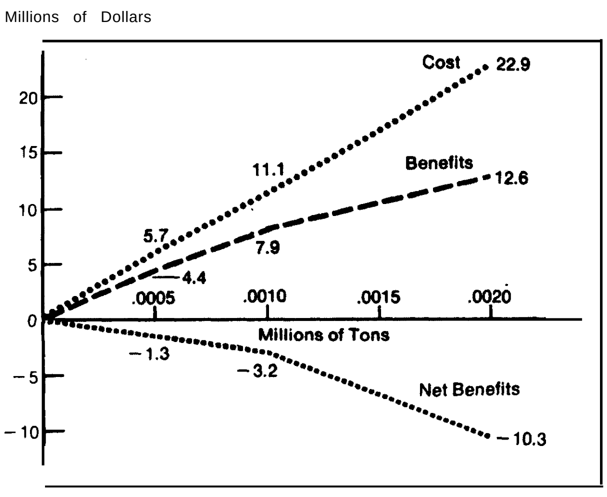
e. Optimal Stockpile Size.—The net benefit curve in figure V-13 can be used to indicate the probable optimal stockpile size, where the curve appears to be at a maximum positive value (or minimum negative value). This can only be taken as an indication of the area where the optimal occurs; however, it will serve to illustrate the desired value of the stockpile size for the values of the input variables chosen. It should be emphasized that the estimates apply only to the specific materials examined and within the scenario assump-

Table V-18.—Input variables SP-4

Math symbol	Program symbol	Description	Units	on J, or J=1	J=2	J=3
Q_j	Q	Stockpile size	Millions tons	0.0005	0.001	0.002
C	Cu	Unit cost	$ per ton	8755.5	9011.0	9522.0
C_f	CF	Fixed initialization cost	Million $	0.5		
C"	CV	Variable initialization cost	$ per ton	0.0		
	XI	Interest rate	Percent per year	0.08		
d	SLR	Spoilage loss rate	Percent per year	0.0		
S	SC	Storage cost	$ per ton per year	2.5		
EC_j	EC	External cost	Million $	3.529	7.284	15.352
Po	PO	Price in current time period without stockpile acquisition	$per ton ,	8500.0		
P'_{0j}	POP	Price with acquisition of stockpile j	$ per ton	9500.0	10900.0	13300.0
P,	PT	Price in future without stockpile disposal	$ per ton	12500.0		
P'_{tj}	PTP	Price in future with disposal of stockpile j	$ per ton	10900.0	9300.0	6200.0
i	DR	Discount rate	Percent per year	0.08		
tf		Time horizon	Years	6.0		
Q_{0j}	E	Size of stockpile j accumulated in current time period	Millions tons	.0005	.001	.002
Q_{tj}	QT	Size of stockpile j disposed in future time period	Million tons	.0005	.001	,002
EDtj	EDT	External damages saved in future time period w/disposal of stockpile j	Million $	5.484	10.676	20.338
d_t	DT	Demand in period t without a stockpile	Million tons	.004384		
Cd	CD	Unit disposal cost	$ per ton	.0		
Q_{dj}	QD	Stockpile disposal cost	$ per ton	.0		

Figure V-13.

Economic Net Benefits of SP-4



tions described, and should therefore not be taken to indicate that precise quantities of specific materials should or should not be stockpiled. Nevertheless, the nature and magnitude of the estimates are sufficient to indicate that an economic stockpile should be given detailed consideration as one component of a more comprehensive national materials policy and that measuring the benefits or costs of a supply disruption in terms of the probability, rather than the certainty, of a disruption will significantly reduce the quantity of material to be stockpiled.

In this illustration, net benefits are negative for all three stockpile sizes, which suggests that tungsten should not be stockpiled for

Table V–lg.—Calculated results for SP-4

Economic impacts of stockpiling tungsten (Millions of dollars)				
Symbol	Description	J=l	J=2 (Millions of tons)	J=3
		0.0005	0.001	0.002
NB_j	Net benefits	–1.3	–3.2	–10.3
‘j	Benefits function	4.4	7.9	12.6
c_j	Cost function	5.7	11.1	22.9
DN	Damage not averted	5.2	4.5	1.5
	Benefit variables:			
	Consumer savings	6.2	13.2	29.1
	Producer loss	5.0	12.2	25.1
CS_j	Net consumer savings:	0.2	1.0	4.0
	Producer gain	4.2	11.0	25.8
	Consumer loss	4.0	9.9	21.0
PG_j	Net producer gain	0.3	1.2	4.8
CF_j	Capital gains	0.4	–1.0	–8.9
ED_j	External damage	3.4	6.7	12.8
	Cost variables:			
HC_j	Holding costs (discounted)	1.6	3.3	7.1
	Initialization costs	0.5	0.5	0.5
DCj	Disposal costs,	0.0	0.0	0.0
OCj	Operating costs	4.8	11.2	30.0
AC_j	Acquisition costs,	4.4	9.0	19.0
•*	Economic impact of no stockpile	4.4	7.9	12.6

All calculations have been rounded off for simplicity
**The economic impact of no stockpile is equivalent to the benefits (expected damages averted) attributed to the stockpile which are foregone in the absence of the stockpile

SP-4. However, a stockpile size less than 500 tons might yield positive net benefits. A longer time horizon for holding the stockpile could yield considerably higher prices of tungsten in period t though the present value of benefits (and cost) become increasingly smaller as the time horizon is extended.

f. Sensitivity Analysis for SP–4.—The computer program performs the “baseline” calculations and then automatically perturbs an input variable by +10 percent and reruns the calculations. The new costs, benefits, and net benefits are compared to the baseline calculations and the percentage change is computed. This process is repeated for each input variable.

The resulting percent changes in net benefits from a +10-percent change in each input variable for SP–4 are listed in table V–20,

An examination of table V-20shows the net benefits to be fairly sensitive to most of the input variables, but not exceeding about plus or minus 90 percent. The maximum changes occur for variations in (a) external damages saved in future time period with disposal of stockpile, and (b) external cost.

The net benefit functions for the baseline case and for perturbations of +10 percent in EDT and EC are plotted in figure V-14. In both cases the net benefits are negative for stockpiles of 0.0005 and 0.001 million tons,

3. Discussion of Partial Benefits and Costs for Each Phase of Stockpile Operation for SP-4

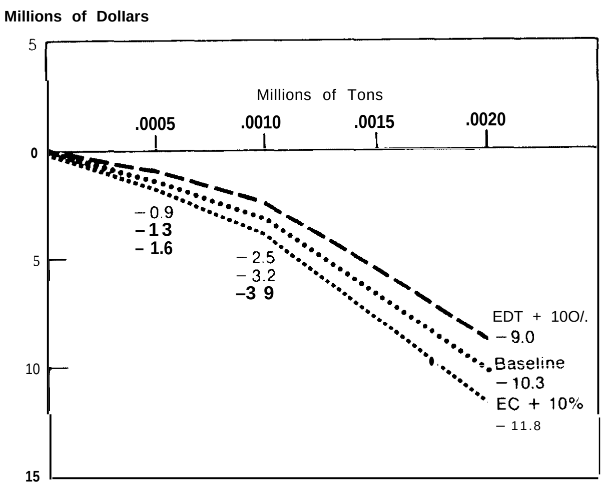
The above presentation of net benefits can be supplemented by a discussion of how the

Table V–20.-Percent change based on 10 percent perturbation of variables for SP-4

Perturbed variable	Benefits			cost			Net benefits		
	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3
CF	0.00	0.00	0.00	0.88	0.45	0.22	3.95	1.57	0.40
Cu	0.00	0.00	0.00	2.86	3.00	3.07	12.77	10.48	6.85
Sc	0.00	0.00	0.00	.01	.01	.01	.05	.04	.02
EC	0.00	0.00	0.00	6.24	6.54	6.70	27.84	22.84	14.93
Po	–4.84	–5.36	–6.73	0.00	0.00	0.00	16.77	13.36	8.27
POP	–1.41	–1.79	–2.74	0.00	0.00	0.00	4.88	4.46	3.37
PT	4.49	4.97	6.23	0.00	0.00	0.00	–15.54	–12.38	–7,66
PTP	3.91	3.70	3.09	0.00	0.00	0.00	–13.55	–9.21	–3.80
TF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
QO	.57	1.51	3.80	0.00	0.00	0.00	–1.97	–3.77	–4.67
EDT	7.85	8.49	10.14	0.00	0.00	0.00	–27.17	–21.15	–12.47
DT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TF_1	0.00	0.00	0.00	2.87	3.01	3.08	12.82	10.51	6.87
TFX	9.43	8.49	6.20	0.00	0.00	0,00	–32.64	–21.15	–7.62

Figure V 14.

Perturbations for SP-4



total is made up of four categories of impacts. The economic impacts of a stockpile for SP-4 can be determined with the Economic Welfare Model for four types of impacts: direct benefits and costs to materials producers, direct benefits and costs to materials consumers, benefits and costs borne by the stockpile investor, and external benefits and costs. Calculations have been made to estimate each of these four types of economic impacts. A tableau arraying the conclusions is presented below for each phase in the operation of a stockpile, followed by the supporting derivations,

a. **Direct Benefit and Costs to Materials Producers.—**Direct benefits and costs to materials producers of a tungsten stockpile under SP-4 are summarized below:

Benefits and costs to producers		Stockpile size (Millions of tons)		
		(Millions of dollars]		
Operational action	Type of benefit or cost	0.0005	0.001	0.002
Acquisition	Producer gain (PG)	4.245	11.088	25.776
Holding	Producer loss (PL)	0.000	0.000	0.000
Disposal	Producer loss (PL')*	5.993	12.237	25.084

“This term is expressed as a present value

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b. Direct Benefits and Costs to Materials Consumers.—Direct benefits and costs to materials consumers of a tungsten stockpile under SP-4 are summarized below:

Benefits and costs to consumers		Stockpile size (Millions of tons)		
		(Millions of dollars)		
Operational action	Type of benefit or cost	0.0005	0.001	0.002
Acquisition	Consumer loss (CL)	3.995	9.888	20.976
Holding	Consumer savings (CS)	0.000	0.000	0.000
Disposal	Consumer savings (CS')*	6.245	13.245	29.053

"This term is expressed as a present value.

c. Costs and Benefits to the Stockpile Investor.—The cost and benefits to the stockpile investor for a tungsten stockpile under SP-4 are summarized below:

Revenues and costs to stockpile operators		Stockpile size (Millions of tons)		
		(Millions of dollars)		
Operational action	Type of benefit or cost	0.0005	0.001	0.002
Acquisition	Initialization cost (IC)	0.500	0.500	0.500
Holding	Holding cost (HC)*	1.625	3.344	7.066
Disposal	Disposal cost (DC)	0.000	0.000	0.000
	Capital gains (CG)	0.441	–1.008	–8.948

"This term is expressed as a present value

d. Estimation of External Costs and Damages.—The estimation of external costs and damages can be done in a generalized, first-order approximation, or it can be rigorously determined. The illustrative calculations for a tungsten stockpile under SP-4 utilize the first approach, a general approximation. The resulting external benefits and costs as given in the tungsten example are summarized below:

External costs and damages		Stockpile size (Millions of tons)		
		(Millions of dollars)		
Operational action	Type of benefit or cost	0.0005	0.001	0.002
Acquisition	External cost (EC)	3.529	7.264	15.352
Holding	External damage (ED)	0.000	0.000	0.000
Disposal	External damage (ED')*	3.443	6.728	12.813

"This term is expressed as a present value.

4. Summary of Economic Net Benefits and Partial Benefits for SP-4

The results of the calculations for SP–4 are summarized in table V–21. These results are for the entire time horizon of the operation of the stockpile, with acquisition being in year 1, the holding phase over years 1-6 and disposal in year 7, In the initial year of operation, large external consumer costs are incurred. During disposal, external damages are avoided and gains in consumer surplus are captured.

For a complete discussion of the Operating Cost Model and estimates of the costs of implementing and running an economic stockpile, refer to the section in chapter VI on Budget Cost Implications. The operating costs are indicated here for conceptual understanding, The cost to the Government of establishing a 500-ton" tungsten stockpile is estimated to be about $4.8 million in the first year, with the major components being $4.4 million for purchase of tungsten plus **$0.5** million for purchase of storage and other facilities and $1.6 million for holding costs. Offsetting these costs are capital gains of $0.4 million. In each succeeding year the cost of operation would only be the holding costs minus the capital gains if the stockpile size remains unchanged,

On balance, materials consumers realize a small net gain, with materials producers being approximately even over the full cycle. Consequently, only nominal transfer payments occur in this illustration. Nonetheless, the distributive effects can be significant. External costs and damages are large, but their distributive effects are unknown. Moreover, because this policy is concerned with the use of resources over time, the discount rate used determines distribution in another sense, namely, between present and future generations. The lower the discount rate the greater is the preference given to future users.

Table V–21.—partial economic benefits and costs of SP–4 for the fuIl cycle of operations

(In millions of dollars)

Type of benefit or cost	Size of stockpile [Millions of tons]	Operational actfon*		
		Acquisition	Holding	Disposal
		PG_j	PL_j	PL'_j
Producers. ., ...	0.005	4.2	0.0	6.0
	0.001	11.1	0.0	12.2
	0.002	25.8	0.0	25.1
		CL_j	CSj	CS'_j
Consumers. . . . . , ...	0.005	4.0	0.0	6.2
	0.001	9.9	0.0	13.2
	0.002	21.0	0.0,	29.1
		IC_j	HC_j	(DC+CG)
Stockpile operators ... , , .	0.0005	0.5	1.6	0.4
	.001	0.5	3.3	–1.0
	.002	0.5	7.0	–8.9
		EC	ED_j	ED'_j
External costs. ... , ...	0.005	3.5	0.0	**3.4**
	0.001	7.3	0.0	**6.7**
	,002	15,4	0.0	**12.8**

Economic net benefits are –1.3 millions, **–3.2 millions, and –10.3** millions for 0.0005, 0.001, and 0.002 million tons of stockpile, respectively.

"Signs indicate the sign **which each term should have when summing to indicate net benefits**

F. ECONOMIC IMPACTS OF STOCKPILING TO PROVIDE A MARKET FOR TEMPORARY SURPLUSES AND EASE TEMPORARY SHORTAGES (SP-5)

The procedure for calculating the benefits of SP–5 is similar to that developed for the benefit function of SP–3. The cost function for SP–5 also takes the same form as for SP–3, as discussed in chapter IV on the Economic Welfare Model, equation (7). The benefit function for SP–5 is developed in the subsequent paragraphs. Calculations of the net benefits are presented immediately thereafter.

1. Derivation of the Benefit Function for SP-5

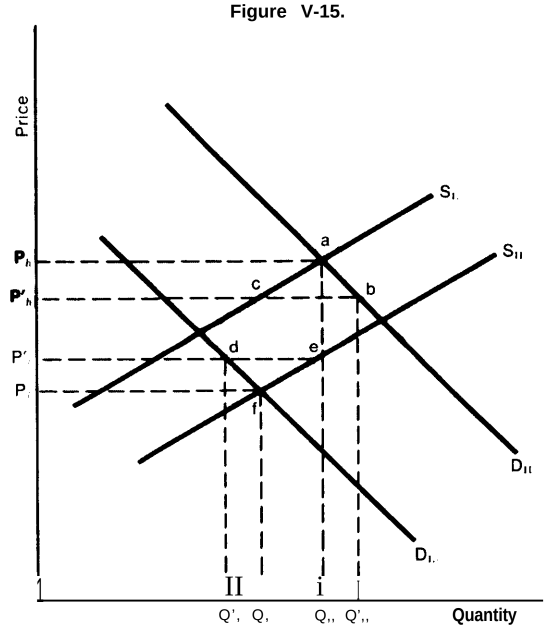
The objective of this stockpiling policy is to stabilize the price of a material around its long-run (market clearing) trend. Attempts to keep the price either above or below the market clearing level in the long run are inconsistent with the stated objective of SP–5, and in fact a stockpile used for this purpose is almost certain to fail. If price is maintained above the long-run level, stockpiles tend to grow increasingly larger over time. If price is maintained below the long-run level, stockpiles are sooner or later depleted.

This stockpiling policy produces four types of benefits: an increase in consumer-producer surplus, a decrease in production costs, a reduction in the external costs associated with price instability, and the realization of capital. The increase in consumer-producer surplus, as shown below in figure V-15, arises because the gain in consumer surplus exceeds the loss in producer surplus caused by stockpile accumulations and the gain in producer surplus exceeds the loss in consumer surplus caused by the disposal of stockpiles.

The decrease in production costs arises because both producers and consumers of the material can, with a stockpile, operate at a more stable production rate. During periods of shortages, producers are not forced to put obsolete and expensive equipment into service, and during periods of surpluses, they do not have to idle production capacity. Therefore, capital and fixed costs are reduced for the producers of the material. The case is similar, though to a lesser extent, for the material consumers,

The reduction in external costs reflects the benefits of greater stability realized by third parties other than producers or (direct) consumers of the material. For example, the suppliers and workers of producing firms during periods of surpluses would now be kept more fully occupied, Similarly, the suppliers and workers of firms indirectly consuming the

Figure V-15.



TERMS:

S, = low supply curve
S, = high supply curve
D = low demand curve
D, = high demand curve
P = high price without stockpile
P' = high price with stockpile
P, = low price without stockpile
P', = low price with stockpile
Q, = high consumption without stockpile
Q', = high consumption with stockpile
Q, = low consumption without stockpile
Q' = low consumption with stockpile

material would no longer face interruptions in production during periods of shortages. Capital gains are realized on the operation of the stockpile because stocks are accumulated during periods of surpluses when prices are low and disposed of during periods of shortages when prices are high.

The benefits from a stockpile of a given size over the entire surplus-shortage cycle should be estimated to calculate the benefit function for this type of stockpile over the coming time period. Since these benefits are derived over the entire surplus-shortage cycle, only a portion of these benefits should be credited to the coming time period. This portion t is given by the ratio of the length of the coming period to the expected length of the surplus-shortage cycle. Thus, the benefits associated with a stockpile of size Q_j over the coming time period can be calculated by:

$$B_j = t(CS_j + PS_j + ED_j + CG_j) \qquad (24)$$

where

- B_j = benefits expected for stockpile of size Q_j
- t = portion of surplus-shortage cycle occurring in the coming time period
- CS_j = increase in consumer-producer surplus
- PS_j = decrease in average production costs
- ED_j = external damage, external costs saved
- CG_j = capital gains

The increase in consumer-producer surplus over the surplus-shortage cycle can be estimated using the procedure described below, which is based on the following assumptions:

- The price of the material reflects the benefits to marginal consumers (i.e., consumers who do without if asked to pay more for the material), as well as the production costs of the management producer;
- The demand and supply curves are linear within the range of the price fluctuations, and
- No sharp increase or decrease in the long term market clearing price occurs over the surplus-shortage cycle.

Let ph be the highest price and p_l the lowest price at which the material would be sold over the surplus-shortage cycle in the absence of stockpiling. This fluctuation in price could be caused by a shift in the demand curve, a shift in the supply curve, or shifts in both curves. In the latter case, demand could increase when supply was increasing, thereby tending to reduce price fluctuations, or demand could increase when supply was falling (as illustrated in fig, V–15), thereby tending to accentuate price changes. The p'_h and p'_j are the high and low prices, respectively, that occur with a stockpile. If over the cycle half of the material in the absence of stockpile were sold at p_h and half at p_l, the increase in consumer surplus during the accumulation of the stockpile would be given by the trapezoid $p_h a b p_h$ and the loss in producer surplus by the trapezoid $P_h a c P'_h$ so that the net gain in welfare would be represented by the triangle abc. This triangle can be approximated by 1/2 (ph-p'h)Q*j where Q^*_j equals the amount of stocks acquired during the accumulation phase (cb in fig. V-15) and sold during the disposal phase (de in fig. V-15). It is possible for Q^*_j to be smaller than the size of the stockpile (Q_j) if the latter is not entirely exhausted over the cycle.

During the disposal phase, the increase in producer surplus is given by the trapezoid $p_l d f p_l$ for a net gain in welfare equal to the triangle def, which can be approximated by 1/2 (P'l-pl) Q*j. Over the entire cycle then, the gain in consumer-producer welfare would equal 1/2 Q*j(pl –pl +ph–p'h). Of course, it is highly probablbly that without a stockpile the price would vary over the range *p]* to *ph so* the increase in consumer surplus would be only some fraction (g) of this amount as indicated in the following equation:

$$CS_j = 1/2 g Q^*_j(p'_l - p_l + p_h - p'_h) \qquad (25)$$

where

CS_j = increase in consumer-producer surplus

g = fraction reflecting distribution of prices

Q_j quantity of stocks accumulated and ed of over cycle

ph = high price without stockpile

ph = high price with disposal of stockpile j

P_l = low price without stockpile

P'_l = low price with acquisition of stockpile j

The increase in consumer-producer surplus is dependent upon the size of the stockpile. That is, the stockpile size determines the level to which the high and low price fluctuations can be dampened, If the stockpile is of sufficient size, all of the price fluctuations will be dampened and the high and low prices would equal the average price (i.e., p'h = p'l = Pa).

The formulation of consumer-producer surplus assumes that the market clearing price remains constant over the cycle considered. If the long-run (market clearing) price tends to change appreciably over the surplus-shortage cycle, the procedure can be adjusted through the normalization of prices around the long-term price trend. The conceptual basis of benefits PS, ED_j, and CGj is the same for SP–3 as that outlined for SP–5 and hence is not *re*-peated here.

The net benefits for SP–5 are calculated for each stockpile size Qj from the benefits determined in equation t24) and the costs from equation (7). The calculations described above should be repeated for stockpiles of various sizes to trace out the entire benefit function and the entire cost function.

2. Estimation of Net Benefits for SP-5

Copper has been selected as a representative material for the calculation of net benefits arising from a stockpile intended to moderate temporary surpluses and shortages. The domestic price and supply of copper has fluctuated considerably over the last 5 years, with fluctuations occurring within a given year and from year to year. For example, the price of copper increased from **68.6** cents per pound in February 1974 to **86.6** cents in July 1974, and then fell to **64.2** cents by February 1975. Over the last 5 years the average annual price has fluctuated between 51,2 cents and 77.1 cents, following supply changes with a lag. Continued uncertainties in the copper industry regarding land restoration, waste disposal, air quality and water supply, combined with the large U.S. reserves of copper ore, are expected to reinforce this price fluctuation,

a. Background Information.—The values and assumptions used in the calculation of net benefits for stockpiling copper under SP–5 are outlined below:

- Future copper prices are assumed to be equal to the prices during the last 5-year cycle. Under this assumption, the high, low, and average prices per ton of copper are respectively **$1,542**, **$1,024**, and $1,283.
- It is estimated that complete stabilization of the price of copper would reduce the average cost of production by 2 cents per pound, with the actual cost reduction being proportional to the percent reduction in price fluctuation.
- External damage averted through reduction of price fluctuations is estimated as the value of unemployment benefits saved, These values are presented in the following table for each of three stockpile sizes:

	Stockpile size in thousand tons		
	500	2500	5,000
Unemployment benefits saved ($ million). . . . . ,	.6	3.0	13.0

b. Input Variables.—The values for the input variables to the computer program for SP–5 are listed in table V–22. This table lists the mathematical symbol, the name, or description of the variable, the units of measure, and the numerical value of the input variable for each I, J, and K. The calculations

Table V–22.—Input variables SP–5

Math symbol	Program symbol	Description	Units	Either not dependent on j, or J=1	J=2	J=3
Q_j	Q	Stockpile size	Million tons	0.5	2.50	5.00
Q'_j	QS	Stockpile accumulations and disposals	Million tons	0.5	1.94	1.94
C_{uj}	Cu	Unit cost	$ per ton	1089.0	1276.0”	1276.0’
C_f	CF	Fixed initialization cost	Million $	0.5		
C_v	CV	Variable initialization cost	$ per ton	0.0		
i	XI	Interest rate	Percent per year	0.08		
d	SLR	Spoilage loss rate	Percent per year	0.0		
s	SC	Storage cost	$ per ton per year	0.39		
t	T	Portion of surplus-shortage cycle occurring in the coming time period	Coefficient	0.2		
cp_j	CP	Unit cost of production saved by stabilization due to stockpiling	$ per ton	14.40	40.00	40.00
s_a	SA	Output of material over the entire cycle	Million tons	11.46		
g	G	Fraction reflecting distribution of prices	Coefficient	0.5		
p_h	PH	High price without stockpiling	$ per ton	1542.0		
p'_h	PHP	High price with disposal of stockpile j	$ per ton	1448.0	1289.0	1289.0
p_l	PM	Low price without stockpile	$ per ton	1024.0		
p'_l	PMP	Low price with acquisition of stockpile j	$ per ton	1089.0	1276.0	1276.0
Q_h	QH	High consumption without stockpile over cycle	Million tons/ 5 year cycle	11.5		
Q'_h	QHP	High consumption with stockpile over cycle	Million tons/ 5 year cycle	12.0	13.432	13.432
Q_l	QL	Low consumption without stockpile over cycle	Million tons/ 5 year cycle	11.195		
Q'_l	QLP	Low consumption with stockpile over cycle	Million tons/ 5 year cycle	10.695	8.696	8.696
ED	ED	External damage-no stockpile	Million $	.600	3.000	3.000
m	M	Fraction of total output over the cycle whose price would be lower than p'_l without a stockpile	Coefficient	.15	.5	.5
h	H	Fraction of total output over the cycle whose price would exceed p’, without a stockpile	Coefficient	15	.5	.5

These costs would he higher than indicated if the entire stockpile of 2 5 or 50 million tons was acquired during the period under consideration The figures shown assume accumulations of 1.94 millions tons during the period under cons] deration

for the SP–5 were performed by the computer program for the input variables listed in table v–22.

c. Calculated (Output) Values.—The values for the output variables calculated by the computer program for SP-5 are listed in table V–23. This table lists the mathematical symbol, the description of the variable, the units of measure, and the numerical value of the output variable for each stockpile j.

d. Graphic Representation of the Calculations.—Figure V-16 is a graphic representation of the calculated costs, benefits, and net benefits (benefits minus costs) for the SP-5. Values are computed only for three stockpile sizes and zero stockpile.

e. Optimal Stockpile Size.—The net benefit curve in figure V-16 can be used to indicate the probable optimal stockpile size, where the curve appears to be at a maximum

Table V–23.—Calculated results for SP–5

Economic Impacts of Stockpiling Copper
{Millions of dollars]

symbol	Description	J=1	J=2 (Millions of tons)	J=3
		0.500	2.500	5.000
NB_j	Net benefits	28.7	–110.4	–366.5
Bj	Benefits function	73.0	146.3	146.3
C	Cost function.	44.3	2.56.7	512.9
DN	Damage not averted	73.3	0.0	0.0
	Benefit variables:			
CSj	Increase in consumer-producer surplus	19.9	244.9	244.9
$PROD\ CST_j$	Production costs saved	165.0	458.4	458.4
CG_j	Capital gains	179.5	25.2	25.2
ED_j	External damage	0.6	3.0	3.0
	Cost variables:			
HC_j	Holding costs.	43.8	256.2	512.4
IC	Initialization costs	0.5	0.5	0.5
DC_j	Disposal costs.	0.0	0.0	0.0
OCj	Operating costs	409.3	3421.5	6867.6
AC_j	Acquisition costs	544.5	3190.0	6380.0
•*	Economic impact with no stockpile	73.0	146.3	146.3

All calculations have been rounded for simplicity
● “The economic impact of no stockpile Is equivalent to the benefits (expected damages averted) attributed to the stockpile which are foregone in the absence of the stockpile

positive value (or minimum negative value). Though this can only be taken as an indication of the area where the optimal occurs, it illustrates the desired value of the stockpile size for the values of the input variables chosen. It should reemphasized that the estimates apply only to the specific materials examined and within the scenario assumptions described, and should therefore not be taken to indicate that precise quantities of specific materials should or should not be stockpiled. Nevertheless, the nature and magnitude of the estimates are sufficient to indicate that an economic stockpile should be given detailed consideration as one component of a more comprehensive national materials policy and that measuring the benefits or cost of a supply disruption in terms of the probability, rather than the certainty, of a disruption will significantly reduce the quantity of material to be stockpiled.

The calculations resulted in an optimal stockpile size of about 500,000 tons accumulated during the surplus portion of the surplus-shortage cycle. The economic net benefits expected for this stockpile are estimated at $28.7 million.

In summary, the example calculations for a copper stockpile show that the required size of a stockpile to stabilize prices and supply can be relatively large. The calculations demonstrate that the optimal stockpile size is not that required to completely stabilize the fluctuations of a materials' supply and price. Stockpile sizes J_2 and J_3 yield the same benefits since both are capable of reducing the price fluctuation close to the average price of $1,283 per ton of copper. * In practice it is recognized that a stockpile—regardless of size—would probably not be able to reduce price fluctuations to the degree assumed in this illustration.

The quantity of copper required to achieve full price stabilization is estimated to be 1.9 million tons, which is less than the sizes

*It is assumed that price fluctuations of 1 percent will continue.

Figure V-1 6.
Economic Net Benefits of SP-5

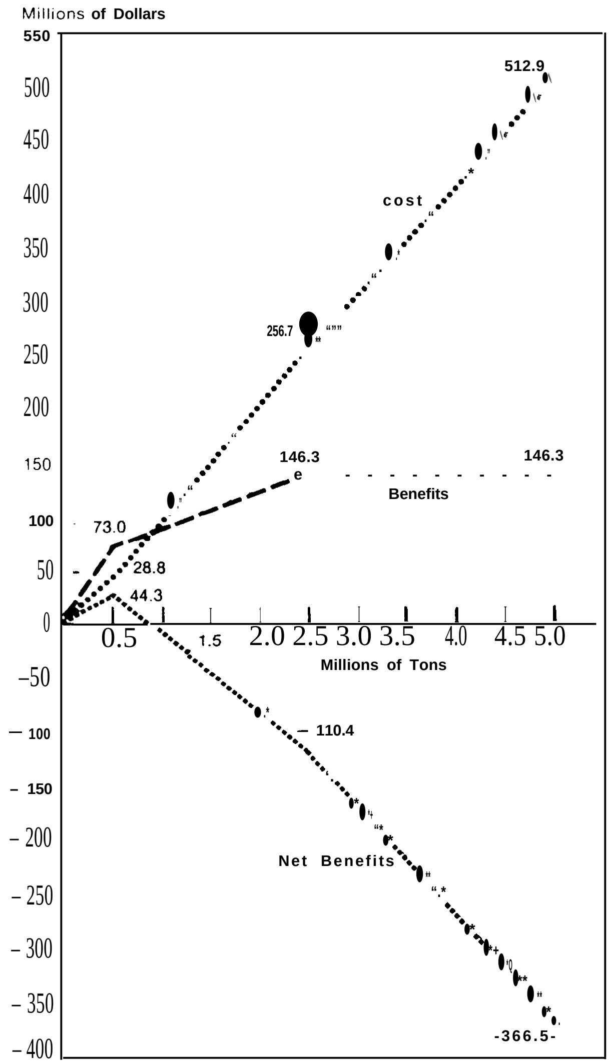
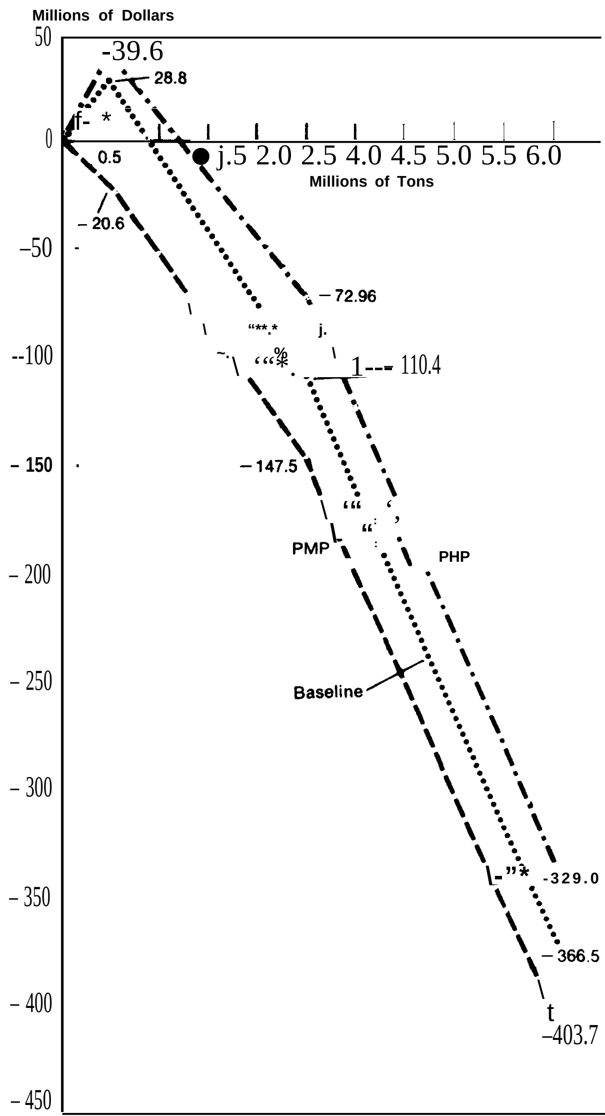


Figure V-1 7.
Perturbations for SP-5



specified for J_2 and J_3. The cost of this stockpile size is $192.3 million, which yields lower but still negative benefits of $52.9 million. The optimal stockpile size is therefore less than 1.9 million tons.

f. Sensitivity Analysis for **SP–5.—The** computer program performs the "baseline" calculations and then automatically perturbs an input variable by +10 percent and reruns the calculations. The new costs, benefits, and net benefits are compared to the baseline calculations and the percentage change is computed. This process is repeated for each input variable.

The resulting percent changes in net benefits from a +10-percent change in each variable for SP–5 are listed in table V–24.

An examination of table V–24 shows the net benefits are fairly sensitive to changes in many of the input variables. The maximum changes are caused by perturbation of (a) high

Table V–24.—Percent change based on 10 percent perturbation of variables SP–5

Perturbed variable	Benefits			cost			Net benefits		
	Q1	Q2	Q3	QI	Q2	Q3	Q1	Q2	Q3
CF	0.00	0.00	0.00	0.11	0.02	0.01	–0.17	0.05	0.01
Cu	0.00	0.00	0.00	9.84	9.94	0.95	–15.15	23.12	13.92
Sc	0.00	0.00	0.00	0.04	0.04	0.04	–0.07	0.09	0.05
ED	0.02	0.04	0.04	0.00	0.00	0.00	0.04	–0.05	–0.02
T	10.00	10.00	10.00	0.00	0.00	0.00	25.40	–13.26	–3.99
CP	4.52	6.27	6.27	0,00	0.00	0.00	11.48	–8.31	–2.50
SA	4.52	6.27	6.27	0.00	0.00	0.00	11.48	–8.31	–2.50
G	0.54	3.35	3.35	0.00	0.00	0.00	1.38	–4.44	–1.34
PH	5.28	10.22	10.22	0.00	0.00	0.00	13.41	–13.55	–4.08
PHP	14.88	25.64	25.64	0.00	0.00	0,00	37.78	–33.99	–10.23
PM	–3.51	–6.79	–6.79	0.00	0.00	0.00	–8.91	9.00	2.71
PMP	–11.19	–25.38	–25.38	0.00	0.00	0.00	–28.41	33.64	10.13
	0.00	0.00	0.00	9.84	9.94	9.95	–15.15	23.12	13.92
QS	5.46	3.69	3.69	0,00	0.00	0.00	13.87	–4.89	–'1.47

price with stockpiling (PHP) and (b) low price with stockpiling (PMP).

The net benefit functions for the baseline case and for perturbations of +10 percent in PHP and PMP are plotted in figure V-17. In both cases the net benefits remain positive for a stockpile of 0.5 million tons and negative for stockpiles of 2.5 and 5.0 million tons.

3. Discussion of Partial Benefits and Costs for Each Phase of Stockpile Operation for SP-5

The above derivation of net benefits can be supplemented by a presentation of the component parts of the net benefit function: direct benefits and costs to materials producers, direct benefits and costs to materials consumers, benefits and costs borne by the stockpile investor, and external benefits and costs. Calculations have been made to estimate each of these four types of economic impacts. The costs and benefits shown below by phase of stockpile operation are those expected for the coming time period (i.e., a year) and are equal to one-fifth the costs and benefits realized over the full 5-year cycle.

a. Direct Benefits and Costs to Materials Producers.—Direct benefits and costs to materials producers of a copper stockpile under SP–5 are summarized below.

Benefits and costs to consumers		Stockpile size (Millions of tons)		
Operational action	Type of benefit or cost	0.5	2.5	5.0
		(Millions of dollars)		
Acquisition	Producer cost saved	16.5	45.8	45.8
	Change" in producer surplus**	12.3	149.8	149.8
Holding	None***	.0	.0	.0
Disposal	Producer cost saved'	16.5	45.8	45.8
	Change in producer surplus**	'14.2	'133.2	'133.2

● Benefits are alleviated evenly to the acquisition and disposal phases. Also producers are assumed here to appropriate all of the benefits associated with lower production costs. In practice some of these benefits may be passed on to consumer through lower prices. If so, the distribution of these benefits could be changed to reflect this, though some estimate of the portion of benefits passed on to consumers would have to be made.

● *On the basis of figure V-15, gains in producers surplus are estimated by

$$tg\left[m(P'_l-P_l)\,Q'_l+m/2\,(P'_l-P_l)(Q_l-Q'_l)+1/2\,(P'_l-P_l)Q^*_l\right]$$

and the losses in producer surplus by

$$tg\left[h(P_h-_h)Q_h+h/2\,(P_h-P'_h)\,(Q'_h-Q_h)-1/2\,(P_h-P'_h)Q^*_i\right]$$

Since Q'_l and Q_f reflect the consumption that would occur over the 5 year cycle if low demand and high supply conditions prevailed over the entire period, the gain in producer surplus measured by the first equation above (and loss in consumer surplus) during stockpile acquisition will be overestimated unless these variables are multiplied by m, the proportion of total output over the cycle whose price would be lower than Pi' without a stockpile. Similarly, the loss in producer surplus measured by the second equation and gain in consumer surplus during the disposal phase will be overestimated unless the variables Q'h and Qh are multiplied by h, the proportion of total output over the cycle whose price would be higher than p'h without a stockpile.

● **The mere holding of stocks, as opposed to acquiring or disposing of stocks, is not assumed to affect prices or generate benefits. In practice, however, this may not always be the case. In particular, speculative demand may be influenced by the existence of large stocks. This would produce benefits and costs to producers and other groups over the cycle. These benefits and costs could be estimated if the effect of holding stocks on prices were determined.

b. Direct Benefits and Costs to Materials Consumers.—Direct benefits and costs to materials consumers of a copper stockpile under SP–5 are summarized below:

Benefits and costs to consumers		Stockpile size (Millions of tons)		
Operational action	Type of benefit or cost	0.5	2.5	5.0
		(Millions of dollars)		
Acquisition	Change in consumer surplus*	-10.7	'125.3	'125.3
Holding	None	.0	.0	.0
Disposal	Change in consumer surplus*	16.6	157.7	157.7

● Gains in consumer surplus are estimated by

$$tg\ \ h(P_h-P'_h)Q_h+h/2(P_h-P'_h)(Q'_h-Q_h)$$

and 1oss by

$$tg\ \ m(P'_l-P_l)Q'_l+m/2(P'_l-P_l)(Q_l-Q'_l).$$

c. **Costs** and Benefits to the Stockpile Investor.—The costs and benefits to the stockpile investor of a copper stockpile under SP-5 are summarized below:

Benefits and costs to consumers		**Stockpile size (Millions of tons)**		
Operational action	**Type of benefit or cost**	**0.5**	**2.5**	**5.0**
		(Millions of dollars)		
Acquisition	Initialization cost	0,5	0.5	0.5
Holding	Holding cost	43.6	256.2	512.4
Disposal	Disposal cost	0.0	0.0	0.0
	Capital gains	35.9	5.0	5.0

d. Estimation of External Costs and Damages.—The estimation of external costs and damages can be done in a generalized, first-order approximation, or it can be rigorously determined. The illustrative calculations for a copper stockpile under SP–5 utilize the first approach, a general approximation. The resulting external benefits and costs as given in the copper example are summarized below:

Benefits and costs to consumers		**Stockpile size (Millions of tons)**		
Operational action	**Type of benefit or cost**	**0.5**	**2.5**	**5.0**
		(Millions of dollars)		
Acquisition	External damage*	0.3	1.5	1.5
Holding	External damage	.0	.0	.0
Disposal	External damage*	0.3	1,5	

● Benefits are allocated evenly to the acquisition and disposal phases,

4. Summary of Economic Net Benefits and Partial Benefits for SP–5

The result of the calculations for SP–5 are summarized in table V–25. These results are for the initial year of operation. For comparison, table V-26 shows the terms in the net benefit function for the second year under the assumption that the relevant input variables are the same. It is assumed that the expected benefits and costs are the same for both years.

For a complete discussion of the Operating Cost Model and estimates of the costs of implementing and running an economic stockpile, refer to the section in chapter VI on Budget Cost Implications. The operating costs are indicated here for conceptual understanding. The cost to the Government of establishing a 500,000-ton copper stockpile is estimated to be about $409 million in the first year, with the major components being $544.5 million for purchase of copper plus $0.5 million for purchase of storage and other facilities and $43.8 million for holding costs. Offsetting these costs are capital gains of $35.9 million. In each succeeding year the cost of operation would only be the holding costs minus the capital gains if the stockpile size remains unchanged,

The distribution of costs and benefits among materials consumers, materials producers, and the stockpile operator differ from the distribu - tion under the previous three stockpile policies. Both consumers and producers are net gainers as a result of implementing this policy, with net gains increasing as the stockpile size increases, It is also interesting to note that the economic costs of stockpiling are borne entirely by the operator—which is not the case in the previous three policies—which in turn means the taxpayer, Consequently, the distributive effects of the cost function cannot readily be ascertained.

Table V–25.—Summary of economic benefits and costs of SP–5 for first year of operation
(In Millions of dollars)

Types of benefit or cost	Size of stockpile millions of tons	Operational action*		
		Acquisition	Holding	Disposal
Producers.	0.500	28.8	0.0	2.3
	2.500	195.6	.0	– 87.3
	5.000	195.6	.0	– 87.3
Consumers.	0.500	– 10.7	0.0	16.6
	2.500	–125.3	.0	157.7
	5.000	–125.3	.0	157.7
Operators.	0.500	– 0.5	– 43.8	35.9
	2.500	– 0.5	–256.2	5.0
	5.000	-- 0.5	–512.4	5.0
External. . . . ., .,	0.500	0.1	0.0	– 0.1
	2.500	0.3	.0	0.3
	5.000	0.3	.0	0.3

Net benefits are $287 millions $-1104 millions, and $-3665 millions for 05, 25, and 50 million ton stockpile, respectively

"Signs indicate t he sign w h ich each term should have when summing to indic ,1 te net benefits

Table V–26.—Summary of economic benefits and costs of SP–5 for second year of operation
(In Millions of dollars)

Types of benefit or cost	**Size of stockpile millions of tons**	**Operational action***		
		Acquisition	Holding	Disposal
Producers.	0.500	28.8	0.0	2.3
	2.500	195.6	0.0	–87.3
	5.000	195.6	0.0	–87.3
Consumers.	0.500	–10.7	0.0	16,6
	2.500	–125.3	0.0	157.7
	5.000	– 125.3	0.0	157.7
Operators.	0.500	–0.5	–43.8	35.9
	2.500	–0.5	–256.2	5.0
	5.000	–0.5	–512.4	5.0
External	0.500	0.1	0.0	0.1
	2.500	0.3	0.0	0.3
	5.000	0.3	0.0	0.3

Net benefits are $28.7 millions, $–110.4 millions, and $-266.5 millions for 0.5, 2.5, and 5.0 million ton stockpile, respectively.

*Signs ı rid]{,,] te the sign w h ıch each term should have when summing to indicate net benefits