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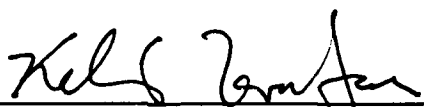RADM. R. W. West, Jr.   Harrison Shull
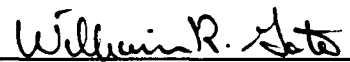Superintendent   Provost

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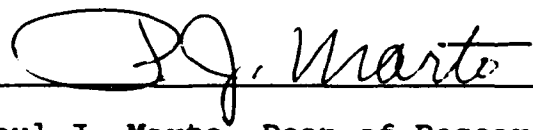
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REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for inrinformation Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management Budget, Paper Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE 31 August 1992	3. REPORT TYPE AND DATES COVERED Technical Report, August 1992

4. TITLE AND SUBTITLE Burden Sharing in the Persian Gulf: Lessons Learned and Implications for the Future	5. FUNDING NUMBERS MIPR S489088
6. AUTHOR(S) Katsuaki L. Terasawa and William R. Gates	

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES) Administrative Sciences Department Naval Postgraduate School Monterey, CA 93943	8. PERFORMING ORGANIZATION REPORT NUMBER NPS-AS-92-020

9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) Program Management Systems Development Agency Army-Chief of Staff 2A690, The Pentagon Washington, D.C. 20310	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

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The analysis concludes that national sovereignty was the more significant of the two benefits and that the oil supply security benefit may be larger for the U. S. than for countries completely dependent on imported oil (i.e., Japan and Germany). Thus, the Gulf countries may have under contributed to the coalition. Japan and Germany may have over contributed, relative to these benefits, though they may have received othere benefits not measured here.

14. SUBJECT TERMS Burden Sharing, Operation Desert Strom, Alliances	15. NUMBER OF PAGES 45
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited

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BURDEN SHARING IN THE PERSIAN GULF: LESSONS LEARNED AND IMPLICATIONS FOR THE FUTURE

Katsuaki L. Terasawa and William R. Gates[*]

INTRODUCTION

Early on August 2, 1990, the armed forces of Iraq invaded and later annexed Kuwait. This increased Iraq's oil resources from 15% to 20% of the Organization of Petroleum Exporting Countries' (OPEC) annual output and increased Iraq's proven reserves from 13% to 25% of OPEC's proven reserves. (Fortune, 1990) Iraq maintained the world's fourth largest military force. Iraq's combined economic and military power enabled them to become a dominant force in the Persian Gulf. Considering that Saddam Hussein, Iraq's leader, had visions of reuniting the Arab population and challenging Israel's existence (Nonneman, 1990), Iraq threatened it's Arab neighbors and the regional power balance.

A multinational coalition was established to counter the Iraqi threat. Backed by 12 United Nations (UN) resolutions (Neff, 1990), the coalition sought Iraq's unconditional withdrawal from Kuwait. Initially, the coalition relied on economic sanctions and diplomatic negotiation. The UN set a January 15, 1991 deadline for Iraq's withdrawal from Kuwait. On January 16, when sanctions and diplomacy had not succeeded, the multinational coalition turned to military force in an effort dubbed "Operation Desert Storm."

The United States was the dominant member of the coalition forces. This lead to U.S. concerns, particularly early in Operation Desert Storm, that many countries benefiting from the coalition's actions were "free riding" (i.e., contributing less than their fair share to the coalition forcing the U.S. to foot the bill). This concern applied to members supplying both military forces and financial aid. Burden sharing can be a divisive factor in international political and economic relationships.

This paper will examine burden sharing in Operation Desert Storm. In particular, it will examine defense alliances models and data from Operation Desert Storm to see what theoretical and empirical evidence suggests about the distribution of the defense burden. With the apparent dissolution of the WARSAW Pact, actions such as Operation Desert Storm may be the most likely type of future deployment for U.S. forces.[1] Understanding burden sharing in this context would help prepare for this possibility.

BURDEN SHARING IN DEFENSE ALLIANCES

The economic theory of alliances is based on public goods theory. A public good is any good where consumption is nonrivalrous and nonexcludable. Nonrivalrous consumption means that several individuals can simultaneously consume a good without affecting the value anyone receives from that good. Nonexcludability means that it is impossible or prohibitively expensive to deny access to any consumers, irrespective of their payments for the good.[2]

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[1]This was reflected in an August 2, 1990 speech by President Bush in Aspen Colorado and in the Secretary of Defense's annual report. (Cheney, 1991)
[2]Street lights satisfy both criteria of public goods. They are nonrivalrous because many pedestrians and vehicles can simultaneously consume the light. They are nonexcludable because it is virtually impossible (or prohibitively expensive) to deny anyone access to street lighting once it is installed.

Olson and Zeckhauser (1966) were among the first to hypothesize that defense alliances provide public goods. Based on this hypothesis, they concluded that defense alliances will provide less than the optimal amount of defense goods and some countries will bear costs exceeding their relative share of the total benefits.

Individual countries making independent decisions will provide public goods until the additional cost of the last unit they provide equals the benefit they receive from that unit. In this decision, individual countries ignore the benefits their expenditures provide_to others (called external benefits). Similarly, each country receives defense benefits from their allies' defense expenditures (called spill-over benefits; external benefits provided by one country become spill-over benefits to its allies). Countries have an incentive to substitute these spill-over benefits for their own defense expenditures. When countries cannot be excluded from enjoying spill-over benefits, they have an incentive to "free ride" (i.e., relying on defense resources provided by other alliance members). External/spill-over benefits limit the total quantity of the public good provided. This creates suboptimality (i.e., the incremental cost of additional units of defense is less than the combined incremental value received by all alliance members). External and spill-over benefits shift costs to those who place a higher value on the public good, as determined by preferences and resources.[3]

It is important to recognize that all alliance members free ride. The opportunity to pass some costs to one's allies in part creates the mutual benefits enjoyed by all alliance members (if an alliance did not provide its

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[3]Disproportionality refers to the distribution of costs and benefits within the alliance. In particular, disproportionality implies that members with the highest value for the public good pay a percent of the costs that exceeds their share of the total benefits. Conversely, members with a low value for the public good pay a disproportionately small cost share.

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members with more defense for a lower cost, members would not voluntarily participate). Because all alliance members free ride, the burden sharing debate really concerns perceived equity and the relative extent of free riding across alliance members.[4] A country becomes dissatisfied if it perceives that its share of the costs exceed its share of the benefits. This is taken as a sign that it is free riding less than its allies.[5]

Mixed Public and Private Benefits

More recently, authors have questioned whether defense expenditures provide purely public benefits. Noting that public goods are nonrivalrous and nonexcludable, Hildebrandt (1990) emphasized that the benefits of purely public defense goods are independent of which member supplies the good. In other words, there are no distinct benefits associated with *ownership of* purely public defense goods. If defense goods are deployed in a way that increases the benefits of the provider, at the expense of the alliance, the goods contain a private element.

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[4]The burden sharing debate focuses on the ratio of costs and benefits across alliance members because measuring the extent of free riding is impossible. Equating the costs/benefit ratio across alliance members is not necessarily optimal or equitable. For example, it does not consider ability to pay or differences in the marginal utility of income or military expenditures. The problem is further aggravated when the ratio of defense expenditures to GDP is used as a proxy for the ratio of costs to benefits. Defense expenditures and GDP are not good proxies for defense benefits and costs. Despite these caveats, the ratio of costs to benefits will be used to measure equity in this paper because it is commonly used in political debates. Gates and Terasawa (1992) discuss equity in defense alliances in more detail.

[5]There is a distinction between efficiency and equity. Efficiency requires increasing the total level of defense until the marginal defense cost to any one alliance member equals the sum of the marginal benefits received by all alliance members. The distribution of the defense burden across alliance members is determined by the member's relative costs. For efficiency, marginal defense costs should be equal for all alliance members. The conditions for efficiency do not consider equity. If the alliance is efficient, there is no guarantee that costs will be proportional to benefits.

Considering this characterization, it seems appropriate to distinguish public from private defense goods by the degree to which the resources are committed to the alliance. (Gates and Terasawa, 1992) Commitment refers here to whether the member providing the resource relinquishes effective control over that resource. Defense goods are fully committed if the provider has transferred all effective control over the asset to the alliance. This ensures that the resource will be deployed to best achieve the alliance's objectives. Fully committed resources are purely public goods. Resource are partially committed if the provider retains some control over the resource. With partial commitment, the provider can deploy the resource in a way which benefits the provider at the alliance's expense (e.g., the alliance would have used the resource differently, *ex ante*, if it was controlled by the alliance). Therefore, alliance members are likely to consider the asset at less than it's full value, decreasing external and spill-over benefits. Finally, the resource is purely private if the provider retains complete control over the resource and it's expected deployment is not likely to provide the alliance any benefit (i.e., there are no external or spill-over benefits). As the ratio of private to public benefits increases, external/spill-over benefits decreases and equity increases.[6]

Inequities also decrease in commitment based alliance models when long-term relationships are important. When alliance members are concerned with maintaining long-term relationships (including defense, political and economic

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[6]Other authors distinguish between public and private defense goods based on the resource's physical characteristics rather than commitment. (Sandler and Forbes, 1980; Murdoch and Sandler; 1982, 1984; Sandler, 1988) This explanation appears inconsistent with Operation Desert Storm where defense resources appear to have provided public benefits regardless of their physical characteristics.

relationships), they may be more cooperative. (Kuenne, 1988; Palmer, 1990)

Cooperation, including bargaining, can increase equity.

BENEFITS FROM OPERATION DESERT STORM

Operation Desert Storm's primary objective was to secure Kuwait's freedom. Over 30 countries supported this objective.[7] These countries all benefited in various ways. Some of the primary benefits attributed to Operation Desert Storm include: preserving national sovereignty, securing the Middle East supply of oil and increasing regional and international stability. All countries can simultaneously consume these benefits and it is impossible to deny any country access once they are secured. Thus, these are public benefits (they are nonrivalrous and nonexcludable). Different countries may receive different values, but that is consistent with public goods theory.[8]

There is one possible exception. The coalition's stated objective was to secure Kuwait's freedom. However, some critics assert that the U.S. had an additional objective: to destroy Iraq's military capability. If this was a U.S. objective, and no other country shared this objective, then the U.S. may have derived some private benefits from Operation Desert Storm. To the extent that the U.S. retains control over its own resources (and those provided by

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[7]Afghan Mujahedeen, Argentina, Australia, Bahrain, Bangladesh, Belgium, Bulgaria, Canada, Czechoslovakia, Denmark, Egypt, France, Germany, Greece, Italy, Japan, Kuwait, Morocco, Netherlands, Niger, Norway, Oman, Pakistan, Poland, Portugal, Qatar, Saudi Arabia, Senegal, South Korea, Soviet Union, Spain, Syria, Turkey, United Arab Emirates, United Kingdom, and the United States. (Bowman, 1990; Defense News, Feb. 4, 1991: 31)

[8]For example, reconsider street lights. Street lights provide several benefits. Motorists benefit from safer driving conditions and pedestrians benefit because street lights make them more visible to motorists and help deter crime. Thus, street lights provide different benefits to different consumers. Each consumer attaches different values to these benefits. Despite differences in valuations, street lights are a public good as long as the benefits are nonrivalrous and non-excludable.

most other coalition members), it could pursue private objectives at the expense of the coalition's overall objectives. However, if destroying Iraq's military capability is the most effective way to achieve the coalition's objective, then U.S. contributions could still be considered public.

Because the benefits were nonrivalrous and nonexcludable, the resources supporting Operation Desert Storm were public goods to the extent that they were committed to the coalition. The commitment based alliance model predicts that disproportionality is likely if participants make independent, voluntary contributions. On the other hand, disproportionality may be modest if alliance members are concerned with maintaining long-term relationships. It is necessary to compare each country's relative cost and benefits to examine the extent to which empirical data indicate inequity. Benefits will be discussed briefly.[9] Costs will be discussed in turn.

National Sovereignty

One obvious benefit is preserving national sovereignty. Kuwait is the prime beneficiary; Saudi Arabia, Bahrain, Qatar, the United Arab Emirates and Israel benefit to a lesser degree. However, the national sovereignty benefit extends beyond the countries directly threatened by Iraq. Operation Desert Storm may also increase the perceived commitment by large countries to protect smaller friendly nations, both formal and informal allies. Increasing this perceived commitment may reduce the necessity for this type of action in the future. Thus, larger countries acting as world policemen, including the U.S.

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[9]This discussion will not address all potential benefits or weigh their pros and cons (e.g., is regional stability best obtained by a U.S. led coalition). It discusses the most commonly cited benefits and their relative values to different countries.

and some Western European countries, receive an indirect national sovereignty benefit.[10] Smaller countries that are potential targets of aggressive neighbors also benefit if increasing the perceived commitment of larger, friendly nations helps forestall this aggression.

Oil Supply Security

Securing Middle East supplies of oil is another benefit attributed to Operation Desert Storm. The initial reaction is to claim that the greatest oil supply security benefit accrues to the countries most reliant on oil from the Persian Gulf. (U.S. Senate, 1991: 22-24) According to this argument, Japan, France and the U.K. received a larger relative oil supply security benefit than the U.S. (See Figure 1a) Only Germany is less dependent on Persian Gulf oil.

However, it is inappropriate to associate the value of oil supply security with reliance on Persian Gulf oil. Oil markets cannot be delineated by source of supply or demand. The world oil market is an integrated market. Changes in one source of supply or demand will affect all market participants. Thus, disruptions in oil supplies from Iraq and Kuwait will have impacts extending beyond consumers relying on those particular suppliers (though countries importing oil from Iraq and Kuwait will bear the short run transactions costs of switching suppliers).

An alternative approach measures the oil supply security benefit by looking at a country's overall reliance on imported oil. According to this

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[10]President Bush acknowledged this U.S. national sovereignty benefit at a news conference on March 1, 1991. According to President Bush, victory in the Persian Gulf reduces the risk that U.S. troops will have to go into battle someplace else in the future. (Griffith, 1991: 2A)

argument, all oil consumers pay more for oil as world oil prices increase.
This creates an income transfer from oil consumers to producers. Oil imports
cause a loss in national income because income is transferred across
international boundaries. Based on this reasoning, world oil price increases
have a larger impact on net oil importing countries. In this case, France,
Germany, and Japan would all receive a relatively greater oil supply security
benefit than the U.S. (See Figure 1b) Conversely, this line of reasoning
implies that net oil exporting countries benefit from increases in world oil
prices. These countries receive a positive income transfer which increases
their national income. Some of the net oil exporters, and their 1989 exports
are summarized in Table 1.
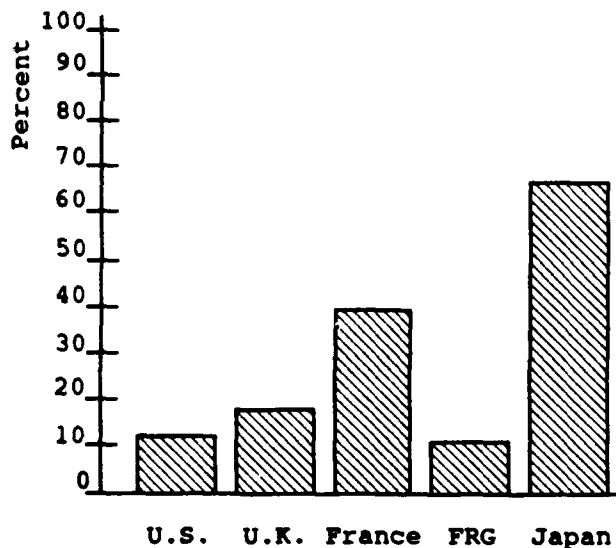
Figure 1a.
Persian Gulf Oil as a Percent
of Total Oil Consumption
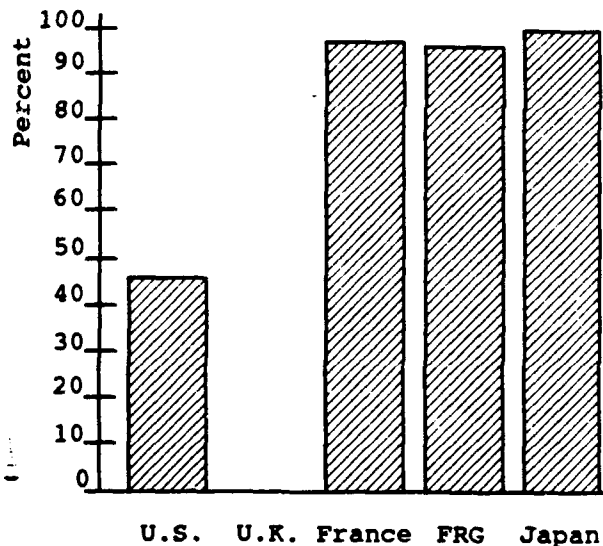
Figure 1b.
Imported Oil as a Percent
of Total Oil Consumption

[a]U.S. Senate, 1991: 22.
[b]Fortune, 1990: 48-49.
[c]International Monetary Fund (IMF), 1990: 34.

Table 1. 1989 Net Oil Exports (millions of barrels)

Coalition Members		Non-Coalition Members	
Saudi Arabia	1,363	U.S.S.R.	1,026
United Arab Emirates	500	Iran	823
Qatar	107	Venezuela	382
U.K.	513	Libya	312
Canada	256	Indonesia	249
		China	202

Source: IMF, 1990: 48-49.

Unfortunately, the value of the oil supply security benefit is more complex than indicated by dependence on foreign oil. The most appropriate measure of this benefit is actually related to the impact that world oil prices have on current and future GDP. GDP's sensitivity to changes in the world oil prices is measured by the elasticity of GDP with respect to changes in the world price of oil (referred to here as oil price elasticity). This measure is defined as the percentage change in GDP divided by the percentage change in world oil prices. It is a unit-less number showing the sensitivity of GDP to changes in world oil prices.

Comparing oil price elasticities will indicate the relative impact of an increase in oil prices on two different countries. The absolute effect on GDP depends on both the oil price elasticity and the magnitude of the oil price change. Both the relative and absolute effects are important in discussing burden sharing in Operation Desert Storm. The relative effects on GDP determine the distribution of the security of oil supply benefit. The absolute effects on GDP determine the significance of this benefit.

Considering oil price elasticity, conventional wisdom may be misleading. The distribution of the oil supply security benefit may not correspond to a country's reliance on either Persian Gulf or imported oil. Countries that have invested in energy efficient manufacturing capabilities may have lower oil price elasticities. Thus, they may suffer a relatively small decrease in GDP as oil prices increase, even if they import more of their oil.

This may well characterize comparisons between the U.S. and both Japan and Germany. Japan and Germany have invested heavily in energy efficient production technologies. Their oil price elasticities may be smaller than in the U.S. If this is true, the relative security of oil supply benefit may actually be larger in the U.S. than in either Japan or Germany.

The Appendix to this paper models the impact of a disruption in world oil supplies on GDP for three hypothetical countries. All three countries consume two final products, oil and an industrial product produced using oil as an input. One country, representing the United States, imports a portion of its domestic oil consumption. The second country, representing Japan or Germany, imports all of its oil. The third country, representing Kuwait or Saudi Arabia, produces only oil and imports industrial products from the other two countries. The model is a general equilibrium model that shows the impact on GDP for all three countries if oil supplies from the oil exporting country are cut in half. In this model, the relative impact on GDP in the oil importing countries depends on the relative oil price elasticities. These elasticities depend in part on the energy efficiency of the manufacturing sector.

In the model, energy efficiency in manufacturing is assumed to be higher for the country importing all of its oil.[11] If there is enough difference between energy efficiencies, the oil price elasticity is smaller for the country importing all of its oil. Thus, its oil supply security benefit would be smaller than for the country importing only a portion of its oil. As the

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[11]Specific values for energy efficiencies used in the model and the resulting oil price elasticities are given in the Appendix. This stylized model is illustrative. It is highly simplified and derives results for hypothetical, though not implausible, parameter values. The intent is to show that "foreign oil dependency" can be a poor proxy for evaluating the economic consequences of an oil supply disruption. Specific model details are discussed in the Appendix.

relative energy efficiency of the oil import-dependent country decreases, its relative oil price elasticity increases. According to this stylized model, the relative impact of an oil supply disruption on GDP depends on both energy efficiency in manufacturing and the level of dependence on imported oil. Neither one alone predicts the relative impacts on GDP.

Several sources estimate GDP elasticities for the U.S. and Japan. For example, Rasche and Tatom (1977b) estimated that the U.S. GDP elasticity was -0.12 for the period between 1949 and 1975. Tatom (1988) estimated that this elasticity was approximately -0.055 between 1955 and 1986. Differences between the two estimates were attributed to data revisions and omission of a productivity growth shift term in the earlier study. Using the same approach as Rasche and Tatom (1977b), Takenaka (1990) estimated that the GDP elasticity was -0.1062 for the U.S. and -0.119 for Japan between 1965 and 1978. Takenaka found that this elasticity fell in Japan to between -0.03 and -0.052 for the period between 1981 and 1986, presumably due to Japan's investment in energy saving capital. Finally, Rasche and Tatom (1977a) hypothesize that the oil price elasticity should approximately equal the share of energy consumption in GDP. In 1989, these shares were approximately 0.048 for the U.S., 0.0118 for Japan, and 0.027 for Germany. (IMF, 1990: 34)

Thus, evidence indicates that the elasticity of GDP with respect to changes in world oil prices may be higher in the U.S. than in Japan and Germany. Consequently, the relative security of oil supply benefit may be lower in these countries than in the U.S.

The overall significance of the security of oil supply benefit depends on both the oil price elasticity and the magnitude of the change in world oil prices. It is clear that Iraq wanted to raise world oil prices. In fact, an oil price dispute was one source of tension between Iraq and Kuwait. In early

1990, Iraq lobbied OPEC to raise oil prices to $20/barrel. (Farouk-Sluglett and Sluglett, 1990) This request was denied and oil prices fell to as low as $14/barrel. Iraq alleged that Kuwait and the United Arab Emirates (UAE) depressed world oil prices by exceeding their OPEC sanctioned production quotas. Iraq claimed Kuwait and the UAE were involved in a Washington encouraged international conspiracy. The conspiracy's alleged intent was to economically destroy Iraq and diminish it's regional power; equivalent to war by economic means. (Nonneman, 1990: 10; Stork and Lesch, 1990: 18). On July 27, 1990, OPEC set a target price of $21/barrel and Kuwait and the United Arab Emirates agreed to adhere to their quotas. (Middle East Report, 1991: 90) However, Iraq charged that Kuwait continued to exceed its quota, leading to Iraq's August 2nd invasion.
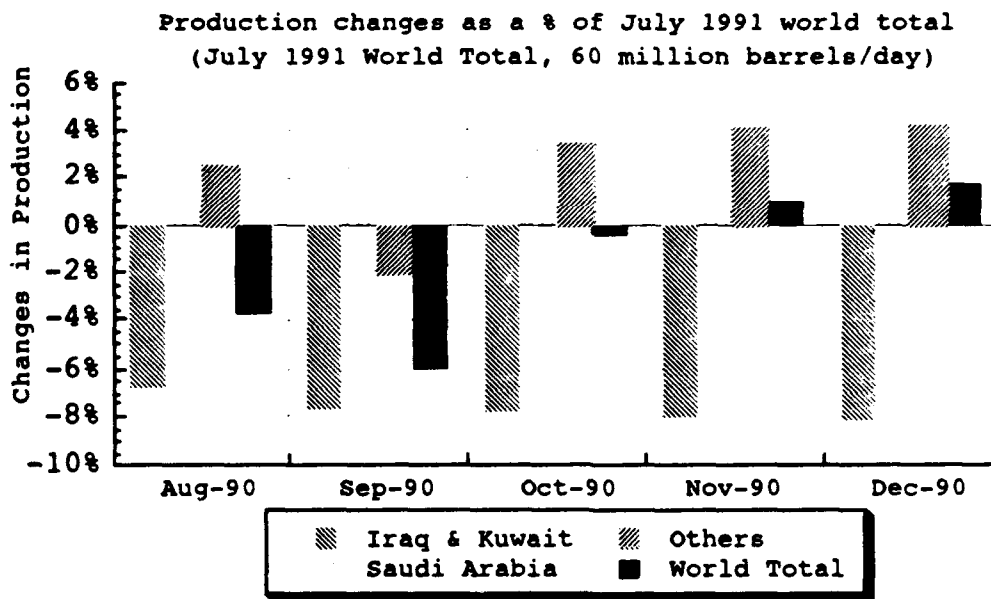
Despite this rhetoric, there are reasons to believe that increases in world oil prices would be temporary and modest, even if Iraq retained possession of Kuwait and annexed the remaining GCC states. If Iraq controlled most Persian Gulf oil, it would likely raise oil prices above $20/barrel. However, oil price increases elicit both a supply and demand response. On the supply side, higher oil prices would encourage other oil producers to increase output in the short run. OPEC's inability to raise oil prices to their target levels since the early 1980's indicates the strength of this incentive. In fact, world oil supplies quickly replaced the oil production lost with the embargo on Iraq and Kuwait (Figure 2). In the long run, higher oil prices would encourage exploration for new reserves and expansion of existing oil production facilities (e.g., in the USSR). These supply side responses would put downward pressure on world oil prices.

On the demand side, higher oil prices encourage consumers to conserve oil and look for alternative energy sources (e.g., natural gas). In addition,

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world GDP falls, further reducing oil demand. Oil price increases can
actually reduce oil revenues if the quantity demanded falls sufficiently.
Henderson (1990) estimates that the revenue maximizing price of oil is
approximately $27/barrel. With competition between suppliers, it is unlikely
Iraq could sustain oil prices at this level. Considering both the supply and
demand responses, it is unlikely that the security of oil supply benefit would
be significant over an extended period of time. More than likely, it would be
modest even in the short run.

Figure 2: Recovery of World Oil Production

Production changes as a % of July 1991 world total
(July 1991 World Total, 60 million barrels/day)

Source: International Energy Administration (EIA), Department of Energy
(DOE), *International Petroleum Statistics*.

Regional and International Stability

Increasing Persian Gulf stability is another alleged benefit.
Instability in the region can be attributed to several factors, including:
growing dissatisfaction with the region's inequitable oil wealth distribution,

increasing frustration over the Palestinian issue, mounting pressure to make governments more democratic, and the growing influence of fundamentalist religious groups. (Andoni, 1990a, 1990b; Graz, 1990; Nonneman, 1990; Stork and Lesch, 1990; Lesch, 1991, Stork and Wenger, 1991) Adding to these instabilities, leaders in several countries wanted to establish themselves as the dominant regional power so they could introduce resolutions that best served their interests. Prior to Iraq's annexation of Kuwait, the primary contenders to the claim of regional hegemon included Iraq, Iran, and Egypt.

The benefits of the coalition's actions vary widely across nations, depending on each nation's perception of the desired regional order and their view of foreign (particularly western) intervention. The Gulf States and Israel probably received the greatest value from this benefit. They have relatively close ties with the U.S. and prefer to maintain the status quo.[12] Egypt and Syria probably received moderate benefits. Both countries have ties to the GCC and the U.S. (though Syria's ties are fairly recent and more tenuous). Both also have strained relations with Iraq. While they might prefer resolving this issue regionally, they are probably less opposed than some to western participation. (Butt, 1990; Saleh, 1990, Lesch, 1991)

On the other hand, some countries probably prefer Iraq's vision of regional stability to the coalition's vision, including countries with particularly strong ties to Iraq, those desiring more radical changes in the

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[12]After the 1979 Iranian revolution, Soviet intervention in Afghanistan, and the Iran-Iraq war, the U.S. and the GCC established military ties. Regional sensitivities precluded overt military ties, but the U.S. received limited permission to use military facilities in Bahrain, Oman and Egypt. More importantly, Saudi Arabia built a $50 billion Gulf-wide air defense system to U.S. and NATO specifications. This system included Airborne Warning and Control System (AWACS) planes and several bases, some designed by the U.S. Army Corps of Engineers, stocked with fuel, parts and munitions. The U.S. intended to provide front-line forces in any crises, after a public invitation from the area's ruling families. (Stork and Wenger, 1991)

status quo and those harboring strong opposition to a western presence in the region (e.g., Jordan, the PLO, and Iran). Many of these countries seemingly supported Iraq, either tacitly or overtly. Unfortunately, Operation Desert Storm's regional stability benefit is virtually impossible to quantify.

For reference, Table 2 summarizes the primary benefits from Operation Desert Storm. These benefits cannot be accurately quantified, so the major participants in Operation Desert Storm have been subjectively categorized into high, medium and low value groups for each benefit. Unfortunately, different benefits do not have comparable values.

Table 2. Benefits From Operation Desert Storm

	Direct National Sovereignty	Indirect National Sovereignty	Oil Supply Security	Regional Stability
High Benefit	Kuwait	U.S.		GCC States Israel
Medium Benefit	Other GCC States Israel	United Kingdom France		Egypt Syria
Low Benefit	Egypt Syria	Germany Japan	U.S. France Germany Japan	

COALITION CONTRIBUTIONS TO OPERATION DESERT STORM

Burden sharing relates contributions to benefits for countries participating in Operation Desert Storm. Thus, it is important to identify each country's contribution to the coalition. Over 30 countries contributed to the operation. The contributions varied widely in content and magnitude. Some members contributed resources (manpower, aircraft, ships, armed vehicles, etc.). Others contributed cash and in-kind assistance to help cover U.S. costs and to aid countries suffering adverse impacts from the conflict and the

embargo on Iraq. Finally, some countries contributed by observing the

economic embargo on Iraq. Each of these contributions will be discussed.[13]

Defense Resource Contributions

Figure 3 shows the manpower contributed by the significant participants

in Operation Desert Storm.[14] The U.S. contributed about 70% of the

coalition's manpower and other military resources. OMB (1991) estimated that

the incremental cost of these resources would exceed $61 Billion (14% for

transportation, 30% for personnel and personnel support, 41% for operating

support and fuel, and 15% for investment and construction). Other countries

also incurred costs for the military resources they provided to Operation

Desert Storm. Assuming similar per capita expenses, costs can be estimated

for countries contributing manpower. (Table 3) These estimates assume that

Saudi Arabia, Kuwait, Egypt and Syria don't incur transportation or investment

and military construction costs.[15]

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[13]There are several other important contributions that are not considered
here. For example, Turkey provided the U.S. access to Turkish air fields and
amassed troops along the Turkey/Iraqi boarder, Germany sent 5 mine sweepers to
the eastern Mediterranean to replace relocated NATO forces and Egypt and Syria
absorbed domestic political costs because there was strong public sentiment
against committing troops. (Bowman, 1991; Abdalla, 1991; Lesch, 1991; Butt,
1990) These contributions are impossible to quantify.

[14]In this discussion, manpower will be used as a proxy for all resource
contributions. In general, relative contributions of aircraft, ships, armored
vehicles, etc. are similar in magnitude to the relative manpower
contributions. Furthermore, other resources are more difficult to summarize
because of differences in physical characteristics (e.g., comparing numbers of
ships assumes that a U.S. aircraft carrier is equivalent to a U.K. guided
missile frigate or destroyer). For ease of presentation, this analysis will
only consider manpower contributions. Similar results would pertain to other
resource contributions. For a more complete description of the resources
provided by other coalition members see Bowman (1990).

[15]If U.S. resources were used more intensely than those contributed by other
countries, these estimates will overstate the actual incremental cost incurred
by other countries. This is supported by preliminary incremental cost
estimates for the U.K ($2.5B) and France ($1.2B). (deBriganti, 1991)

Figure 3. **Manpower Contributions to Operation Desert Storm**
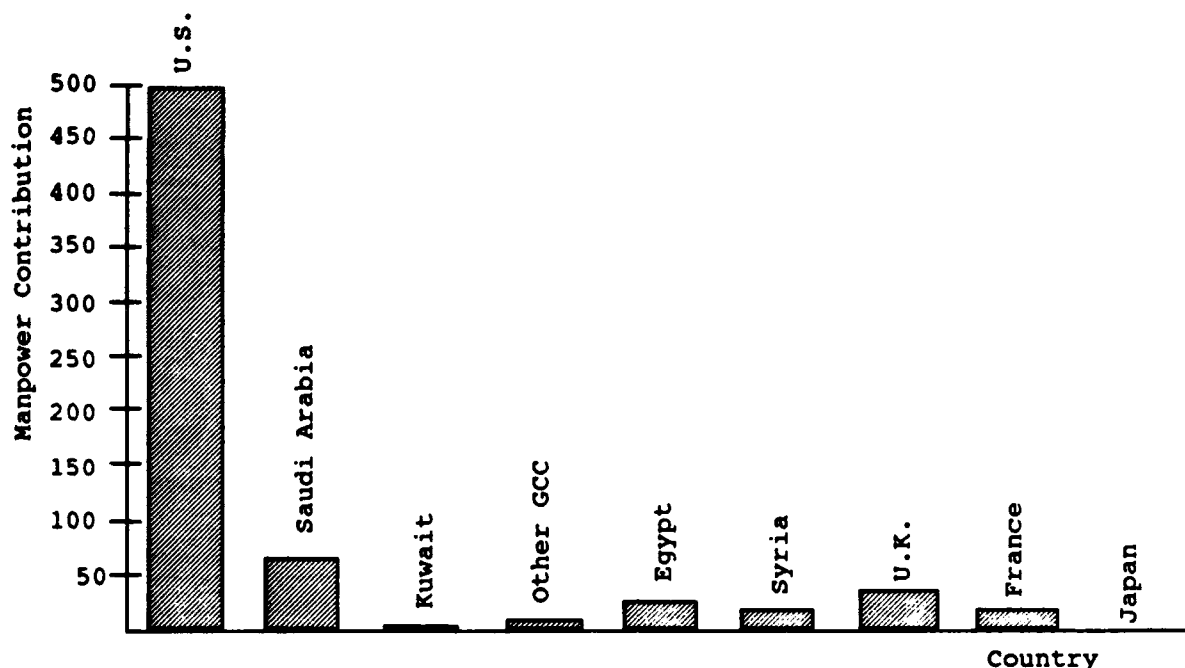
Sources: Bowman, 1990; Defense News, 1991; National Journal, 1991; U.S. Congress, Senate, 1991. All data in these references are not comparable.

TABLE 3: Estimated Incremental Defense Costs of Operation Desert Storm ($ Billions)

Country	U.S.	Saudi Arabia	Kuwait	Egypt	Syria	U.K.	France
Cost ($B)	61	5.6	0.6	2.5	1.7	4.9	2.4

Note: Based on U.S. incremental defense costs (OMB, 1991). Assumes similar per capita personnel and operations costs as estimated for the U.S. for all countries. Assumes similar per capita transportation and investment costs for the U.K and France.
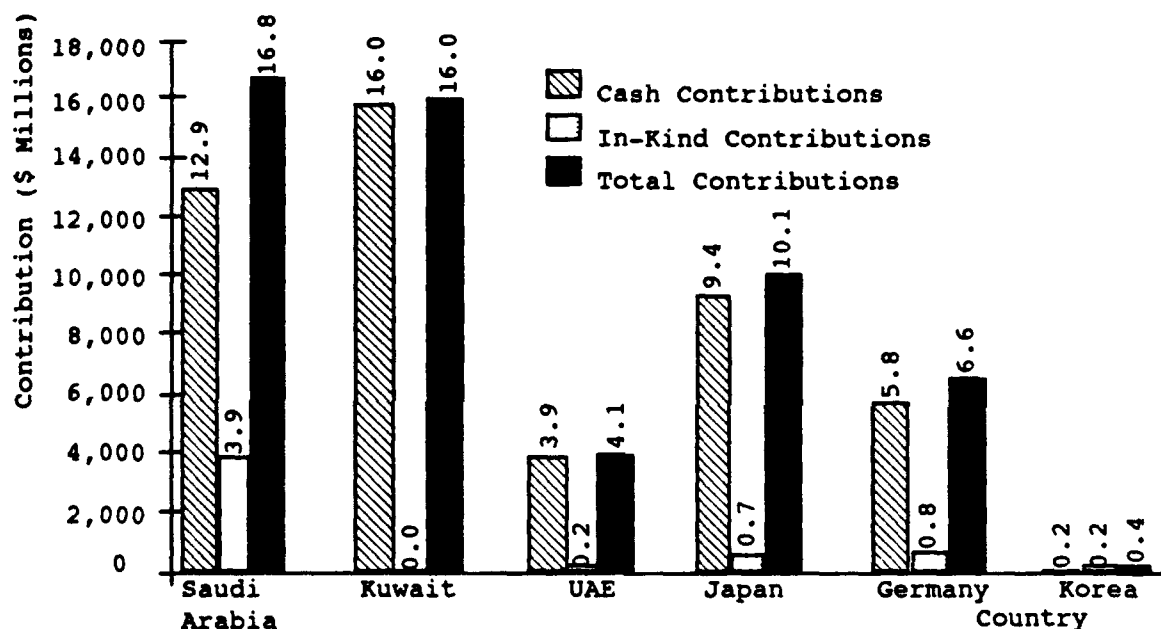
Cash, In-Kind and Aid Contributions

In addition to military resources, some countries pledged cash and in-kind assistance to the coalition. Figure 4 shows the cash and in-kind

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contributions to the U.S. for participants in Operation Desert Storm.[16]

Several countries also provided aid to the "front-line states" (Turkey, Jordan and Egypt) and other countries affected by the economic embargo on Iraq. This aid is part of a country's contribution to Operation Desert Storm.[17] Figure 5 summarizes these contributions for selected coalition participants.

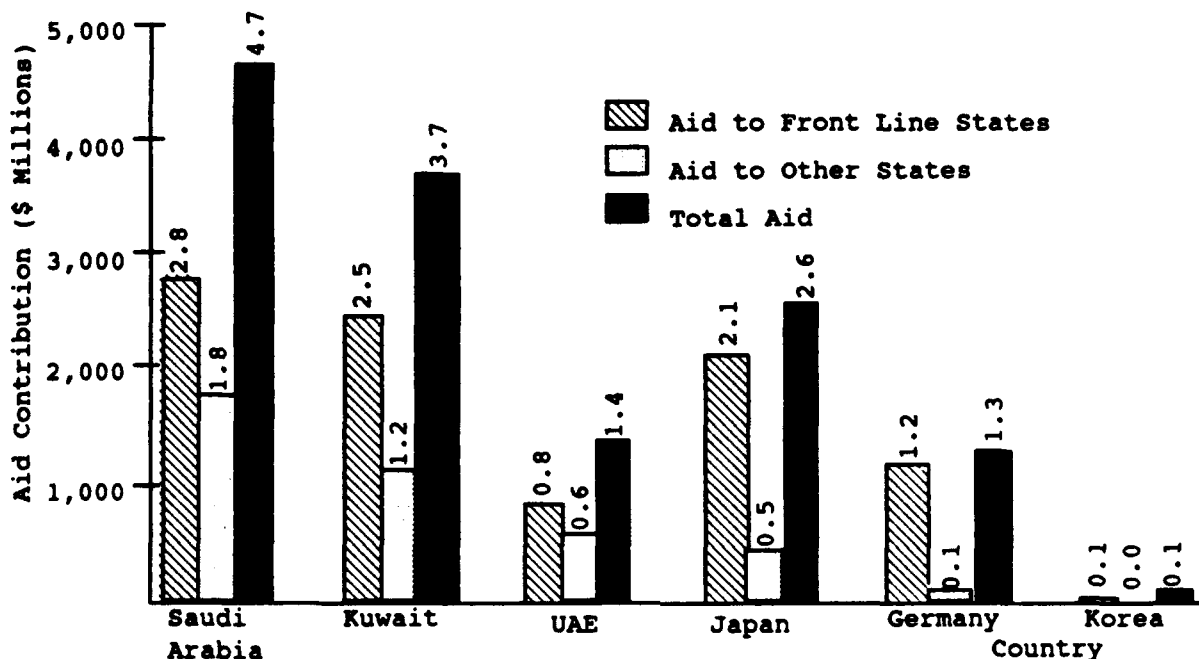**Figure 4. Allied Cash and In-Kind Contributions for Operation Desert Storm**

Contribution ($ Millions)

Cash Contributions
In-Kind Contributions
Total Contributions

Saudi Arabia: 12.9, 3.9, 16.8
Kuwait: 16.0, 0.0, 16.0
UAE: 3.9, 0.2, 4.1
Japan: 9.4, 0.7, 10.1
Germany: 5.8, 0.8, 6.6
Korea: 0.2, 0.2, 0.4

Country

Source: OMB (1991).

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[16]Figure 3 shows each country's pledge to the U.S. (OMB, 1991) These pledges total $53,958M. As of November 15, 1991, $50,487M had been paid. The $3,471M outstanding pledges are being paid according to a schedule established by the U.S. and the respective foreign governments. Saudi Arabia and Kuwait accounted for over $3,200M of the outstanding pledges. OMB (1991) provides a description of the in-kind assistance provided by each country. In addition, Japan provided $700M to the U.K. and France. Korea also provided small contributions to the U.K. and France. (Conahan, 1991)

[17]There are additional contributions that should be included. Consider Egypt. The U.S. has forgiven $7 billion in military debts, the Gulf states have forgiven $7 to $9 billion in debts and Egypt has received close to $10 billion in additional loans (withheld prior to August 2, 1990). (Abdalla, 1991; Parker, 1991) This aid involves direct benefits and costs, but it is difficult to value. For example, the value of debt forgiveness must be discounted by the probability of default and for the time value of the foregone future payments. Similarly, the cost of loans must consider the opportunity cost of the money loaned and the probability of default. For these reasons, only direct cash grants are included in this analysis.

Figure 5: Aid To Front Line and Other States

Figure 5: Aid To Front Line and Other States

Y-axis: Aid Contribution ($ Millions)

Legend:
- Aid to Front Line States
- Aid to Other States
- Total Aid

Saudi Arabia: 2.8, 1.8, 4.7
Kuwait: 2.5, 1.2, 3.7
UAE: 0.8, 0.6, 1.4
Japan: 2.1, 0.5, 2.6
Germany: 1.2, 0.1, 1.3
Korea: 0.1, 0.0, 0.1

X-axis: Country

Source: Conahan (1991).

Costs of the Economic Embargo Against Iraq

Finally, some countries contributed to the coalition by observing the economic embargo against Iraq. For example, Turkey lost revenues associated with Iraq's oil pipeline through Turkey. Egypt lost foreign remittances from workers in Gulf countries, Suez Canal tolls, proceeds from exports to Iraq and Kuwait and tourism revenues. In total, Egypt's losses were estimated at over $3 billion. (Abdalla, 1991; Parker, 1991) Syria, Jordan, Pakistan and several other countries incurred similar costs.

Another cost of the Iraqi embargo involves higher oil prices. The short run increase in world oil prices between August 1990 and January 1991 was more severe than the price increases that would have occurred if Iraq's invasion of Kuwait had been unchallenged. After the embargo on oil from Iraq and Kuwait, oil prices increased due to the combined effects of reduced supply and

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speculative demand. It is unlikely that Iraq would have removed all of this oil from the world oil market, so the supply impact would have been partially mitigated. The presence of some Iraqi and Kuwaiti oil exports may also have reduced speculative demand. Thus, coalition intervention actually increased short run oil prices.

As discussed earlier, higher oil prices cause an income transfer from oil importing to oil exporting countries and cause a reduction in GDP. The International Monetary Fund (IMF) estimated the effect on 1990 GDP if oil prices increased at a 40% annual rate beginning in August 1990. Oil prices averaged $26/barrel in the later part of 1990 in their base case. A 40% annual increase, beginning in August 1990, would increase oil prices by approximately $4/barrel in 1990. Table 5 summarizes the simulation results for the U.S., Japan, Germany, France, the U.K. and all industrialized countries as a group. If the IMF's base case reflects world oil prices with the coalition's intervention and the 40% price increase scenario reflects oil prices with the embargo, the estimates in Table 4 measure the expected impact on 1990 GDP of the coalition's embargo. Actual oil prices increased faster than the IMF high oil price scenario between August 1990 and mid-January 1991, exceeding $40/barrel in October 1990. Thus, Table 4 likely understates the cost burden of the embargo on Iraqi oil.

While GDP in oil importing countries decreased because of the Iraqi oil embargo, oil exporting countries received an increase in oil revenues. In particular, both oil prices and output increased as other producers expanded production to replace the embargoed oil. As a result, both Saudi Arabia and the United Arab Emirates (UAE) received windfall gains. These were at least partially offset by both decreases in GDP due to higher world oil prices and the costs incurred to expand oil production. Estimates are not available for

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the impact of higher oil prices on GDP in Saudi Arabia and the UAE. Saudi

Arabia claims to have spent $4B to expand oil production. The net gain for

both countries is shown in Table 5.

Table 4.   Effects of a 40 Percent Rise in World Oil Prices

	U.S.	Japan	Germany	France	U.K.	Industrial Countries
Baseline Real GDP Growth Rate[a]	1.3	5.1	3.9	3.1	1.4	2.6
Modified Real GDP Growth Rate[a]	1.1	4.9	3.6	2.9	1.2	2.4
% Change in Real GDP[a]	-0.2	-0.2	-0.3	-0.2	-0.2	-0.2
Change in Real GDP (B 1990$)[b]	-10.5	-6.0	-3.8	-2.0	-1.7	N/A

[a]IMF (October 1990), *World Economic Outlook*, Washington, D.C., International
Monetary Fund: 35, 113.
[b]Based on 1989 GDP data, see International Institute for Strategic Studies
(IISS), 1990. 1989 GDP data was escalated to 1990 values using IMF real GDP
growth rates (IMF, Oct. 1990: 113).

Table 5:   Net Windfall Oil Profits ($Billions)

Country	Saudi Arabia	United Arab Emirates
Net Windfall Profit	15.0	5.2

Source: Hinkley (1991).

For reference, Figure 6 combines the costs of defense resources, cash

and in-kind contributions, aid to front-line and other states, and the

indirect costs (windfall profits) of the embargo on Iraqi oil. Recalling the

measurement problems associated with these estimates and that some important

contributions have not been considered, Figure 6 gives a preliminary estimate

of the total incremental cost of Operation Desert Storm.

Figure 6: Total Incremental Cost of Operation Desert Storm
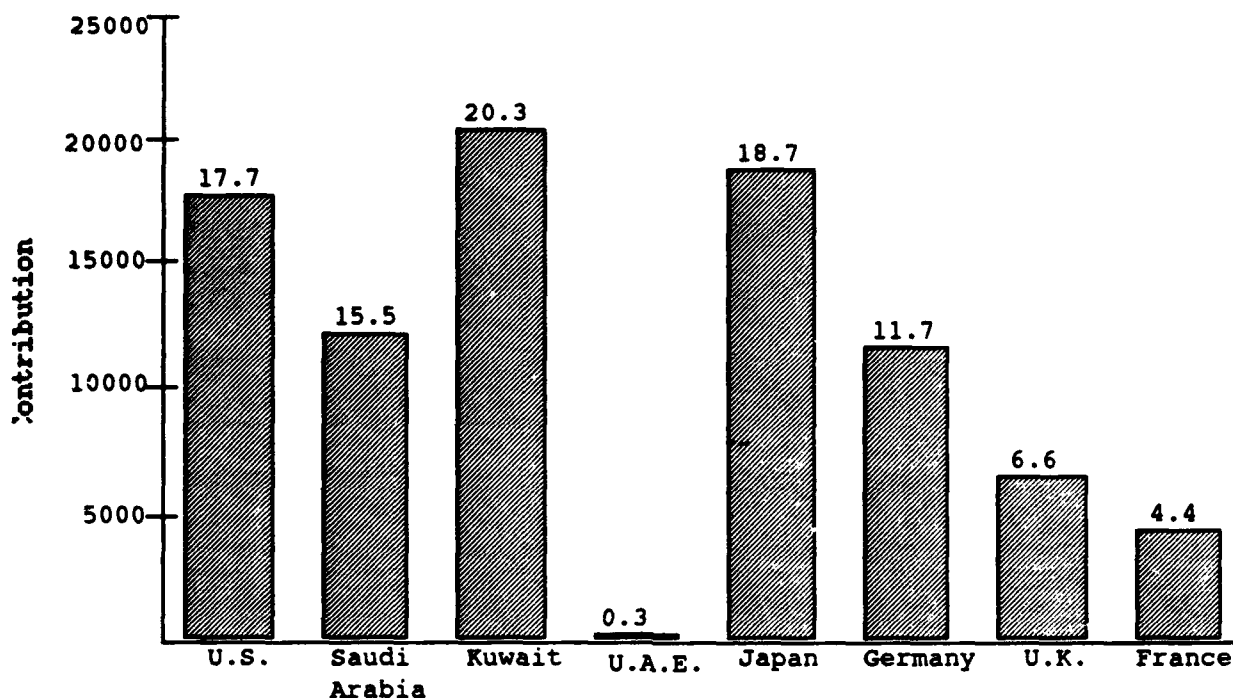
MEASURING EQUITY IN DEFENSE ALLIANCES

The preceding discussion indicates that benefits and contributions vary across coalition members in both type and magnitude. Empirically measuring disproportionality in Operation Desert Storm requires specifying the diverse costs and benefits in common units so their relative values can be compared across coalition members. This introduces significant measurement problems, as discussed above.

Quantitative Equity Measures

The U.S. Senate Budget Committee compared each county's contribution to the coalition's total manpower with their dependence on Persian Gulf imports to assess the burden distribution in Operation Desert Storm. (U.S. Senate,

1991) Figure 7 reconstructs this comparison. According to this comparison, the U.S. is bearing a disproportionately large burden.

Figure 7: Military Manpower Contributions Versus Dependence on Persian Gulf Oil
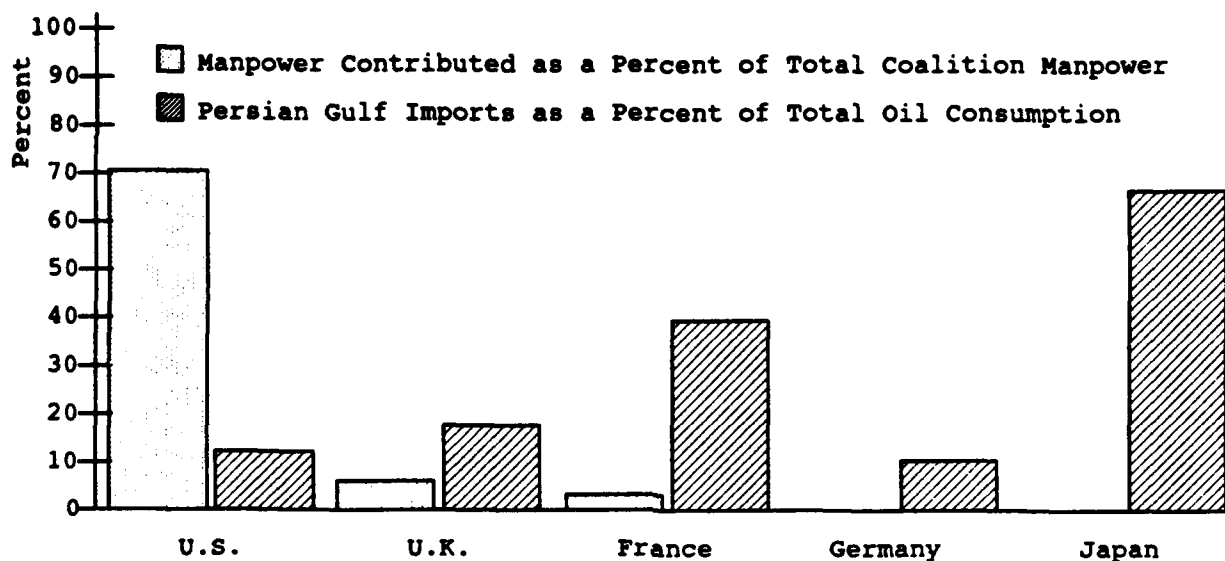
Source: U.S. Senate (1991)

However, there are several problems with this measure. The manpower proxy for contributions ignores other types of defense resources and all financial contributions. Thus, it is biased against Japan and Germany who have made financial contributions. Similarly, the benefit proxy incorrectly measures the oil supply security benefit and ignores all other benefits. For example, the benefits realized by the GCC states, Egypt and Syria can not be captured by this measure.

Defense expenditures and GDP have frequently been used as proxies for defense costs and benefits, respectively. Figure 8 shows defense expenditures as a percent of GDP for the major participants in Operation Desert Storm. This figure uses defense expenditure data from Figure 6. GDP data is from the

International Institute for strategic studies (IISS, 1990). This index indicates that Kuwait and Saudi Arabia have the highest ratio of costs to benefits. They are bearing a disproportionately large burden, according to this index. On the other hand, the U.S., the U.K. and France are bearing disproportionately small burdens.

Figure 8: Incremental Expenditures for Operation Desert Storm as a percent of GDP

Total Incremental Contribution (% of GDP)

	U.S.	Saudi Arabia	Kuwait	U.A.E.	Japan	Germany	U.K.	France
	0.34	15.49	87.91	1.26	0.65	0.96	0.78	0.46
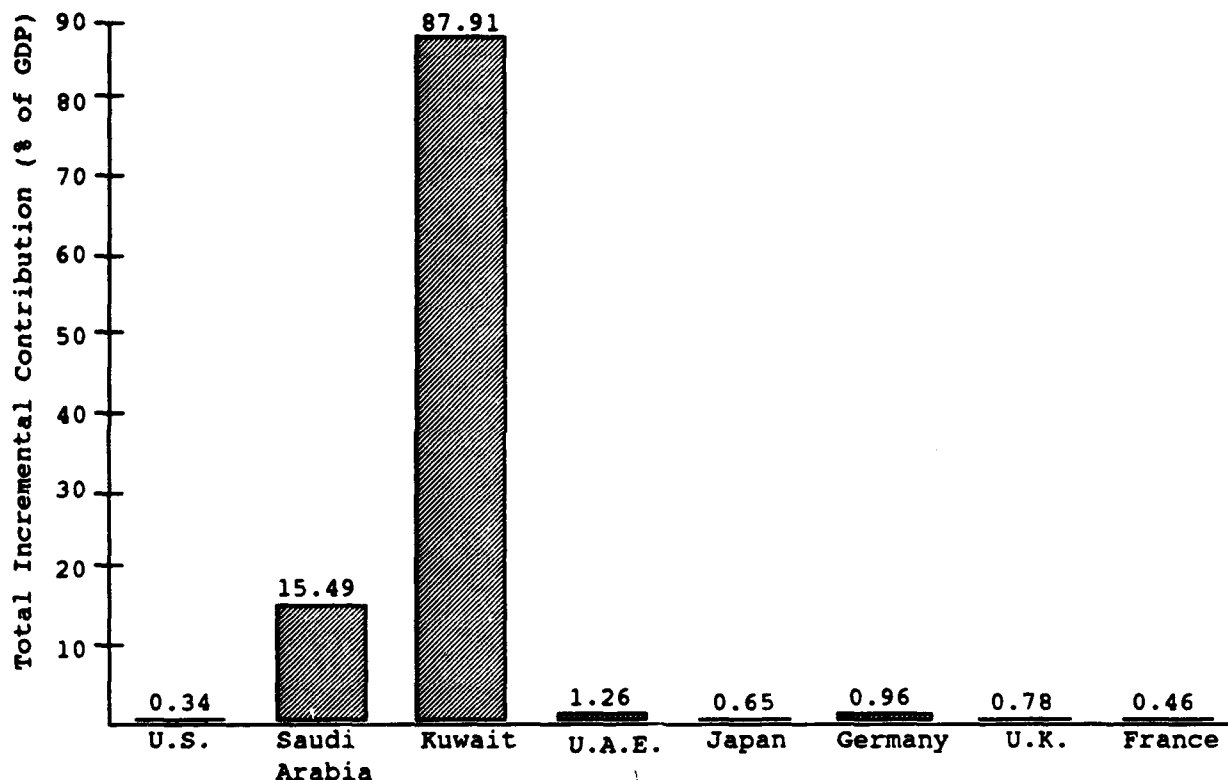
Using GDP as a proxy for defense benefits implies that the objective of defense is to protect a nation's income. However, Operation Desert Storm had several other direct and indirect benefits, as discussed previously. Furthermore, the value of these benefits depends in part on the level of the perceived threat.[18] Defense expenditures become more valuable as the

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[18]Perceived threat in this case measures each country's opinion of whether the Iraqi annexation of Kuwait threatened that country's national sovereignty, regional and international stability, and oil supply security.

perceived threat increases. GDP does not reflect the range of benefits or perceived threat.

Considering the wide range of benefits and threat perceptions, it would not be surprising to observe two nations contributing different amounts to Operation Desert Storm even though they have identical GDPs. This result could even occur if defense burdens were shared equitably. GDP serves as a proxy for defense benefits only if all other factors are identical for all alliance members. If this *ceteris paribus* assumption is violated, the ratio of defense expenditures to GDP cannot measure equitably.[19]

Measurement problems also arise in using defense expenditures as proxies for contributions to the coalition. (Knorr, 1985) Most significantly, in the case of Operation Desert Storm, troop costs are impossible to estimate when troops are at risk.[20] Furthermore, cost estimates must measure the marginal opportunity cost of the troops and equipment *deployed in Operation Desert Storm.* Because marginal costs are hard to estimate, budgetary costs are frequently used.[21] Finally, expenditure data does not consider differences in procurement efficiencies or defense capabilities.

Another common alternative is to measure the actual defense resources provided (e.g., manpower, ships, aircraft, tanks, etc.). (NATO Defence Planning Committee, 1988; Cooper and Zycher, 1989; U.S. Secretary of Defense,

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[19]The ratio of GDP to defense expenditures was first used by Olson and Zeckhauser (1966). They appropriately hypothesized that, *all other things equal*, there will be a significant positive correlation between defense expenditures and a nation's GDP. The *ceteris paribus* assumption has not been explicitly acknowledged in the succeeding studies using this measure.
[20]Troops at risk and expected casualties are important measures of a country's contribution. Before the end of a conflict, the number of actual casualties is uncertain. A country's commitment to the coalition's objectives is measured by it's expected casualties. If actual casualties are lighter than expected, it reduces the total cost the country actually pays. It does not reduce the country's commitment to the coalition.
[21]For further discussion see Hinkley (1991) and Johnson (1991).

1990) Unfortunately, capability related measures have many shortcomings. First, this data does not relate contributions to benefits. Second, it is impossible to combine data on several different resources into a single contribution index. Finally, defense capabilities do not capture the real military value of an ally's contribution. Military value is the joint product of several factors, including: quantity of troops and equipment; capability and condition of military equipment; capability to support and re-supply; and troop training, leadership and morale. (Knorr, 1985) Defense capabilities only measure the first of these factors.

Subjective Equity Assessments

Because of the measurement problems described above, it is impossible to calculate a single quantitative index to compare equity across coalition members. Instead, general impressions can be drawn by qualitatively comparing the coalition members' relative contributions and benefits.

Considering the national sovereignty, oil supply security and regional stability benefits attributed to Operation Desert Storm (recall Table 3), it appears that Kuwait, Saudi Arabia and the other GCC states gained the most from the coalition's actions. They received the greatest national sovereignty and regional stability benefits. These are the most significant benefits.

Japan and Germany probably received the smallest benefits. At best, the security of oil supply benefit is modest in the short run and probably negligible in the long run. Furthermore, Japan's and Germany's indirect national sovereignty benefits are also modest because of their current constitutional limits on military actions beyond their boarders (i.e., limits on their role as world policeman).

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Finally, the U.S. probably received a greater indirect national sovereignty benefit than the U.K. or France. The U.S. places a greater emphasis on its role as world policeman (and/or perceives a greater threat to its view of the appropriate world order) and has closer ties to Israel. The U.S., U.K. and France probably received similar relative values from the other benefits. Thus, the U.S. received greater benefits than either the U.K. or France.

Comparing this ranking of beneficiaries with their relative financial contributions (recall Figure 8), two conclusions become evident: the GCC states, with the exception of Kuwait, appear to have born a disproportionately small share of the Operation Desert Storm burden; Japan and Germany appear to have born a disproportionately large share of the burden. Regarding the GCC states, Saudi Arabia contributed all of its military forces and approximately 25% of its 1989 GDP in cash, in-kind assistance and foreign aide. However, Saudi Arabia also receive windfall oil revenues that offset a significant portion of this financial burden. The situation is worse for the other GCC members. These countries did not directly contribute military forces.[22] Furthermore, the UAE only contributed 14% of its 1989 GDP; the remaining GCC states (Bahrain, Oman and Qatar) did not pledge any of their combined $17.7B 1989 GDP. All of these countries have received windfall oil profits. If these countries had all contributed 25% of their 1989 GDP, as did Saudi

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[22]While none of these countries directly provided troops, the Gulf Cooperation Council maintained a combined force of 10,000 troops from Saudi Arabia, Kuwait, Bahrain, Qatar, Oman and the United Arab Emirates. This force was stationed in northern Saudi Arabia, along with approximately 10,000 Kuwaiti soldiers that escaped following Iraq's invasion. (Bowman, 1991) The costs of these troops have not been estimated in this analysis.

Arabia, their combined contribution would have increased by over $7B. Much of

this cost would still be offset by windfall oil profits.[23]

At the other extreme, Japan and Germany seem to have made financial

contributions exceeding their share of the benefits. It appears that their

primary benefit was maintaining good relationships with the U.S. In

particular, both Japan and Germany significantly increased their contributions

shortly after the war began. These additional pledges appeared to result in

large part from intense U.S. lobbying (Walsh, 1991).[24] With bargaining,

countries valuing the public good more highly (i.e., the U.S.) can encourage

other countries to increase their share of the burden. (Though there might

also have been an increase in the perceived threat as the war approached and

finally became reality.)

IMPLICATIONS AND CONCLUSIONS

The benefits from Operation Desert Storm include national sovereignty,

regional and international stability and oil supply security. These benefits

are nonrivalrous and nonexcludable. Therefore, they are public benefits and

resources committed to the coalition are public goods. Public goods theory

predicts that coalition members will contribute unequally, if contributions

are voluntary and independently determined (i.e., no bargaining). Countries

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[23]At first glance, Saudi Arabia's higher relative contribution appears
justified because they were most directly threatened by further Iraqi
aggression. However, the threat may not have been significantly lower for the
other GCC states, particularly the United Arab Emirates. Iraq had grouped the
United Arab Emirates with Kuwait in its accusat̄ ̃s of excess oil production.
Considering this, and the geographic location anᵤ ̃ilitary power of these
countries, it is not unreasonable to conclude that their national sovereignty
benefit was similar to that received by Saudi Arabia
[24]In Germany's case, the external pressure to contribute was particularly
intense, in part because of Germany's link to Iraq's chemical and biological
weapons capabilities. (Hippler, 1991; Walsh, 1991)

placing the highest value on the public good (as indicated by both preferences and ability to pay) would bear a share of the total costs that exceeds their share of the total benefits. Countries with a lower value for the public good bear a lower share of costs relative to benefits. In fact, some countries may not contribute at all (i.e., the privileged group). Inequities may be reduced through bargaining if countries are concerned about maintaining long run mutual relationships.

Data from Operation Desert Storm was examined to find evidence of inequities by comparing the ratio of costs to benefits for each coalition member. Each country's appraisal of the benefits depends on both the benefits' value and the country's threat perception. Similarly, contributions are difficult to quantify, particularly where lives are at risk. Measurement problems make it impossible to construct a single quantitative equity index. Unfortunately, many measures have been proposed. These measures indicate different balances between costs and benefits across countries. Some may show the U.S. bearing a disproportionately large burden, others may show a disproportionately small U.S. burden. In many cases, they may be selected to demonstrate a particular political viewpoint (e.g., Senate, 1991). Unfortunately, measurement problems make it impossible to construct an objective disproportionality index that is universally accepted.

Subjective assessments can be used in the absence of objective quantitative indices. Subjective assessments indicate that the small GCC members (i.e., United Arab Emirates, Bahrain, Oman, and Qatar), and Saudi Arabia to a lesser extent, may have borne a disproportionately small share of the burden. Considering the U.S.'s relative size and announced intention to repel Iraq whatever the cost, this result is consistent with public goods theory without cooperation. Conversely, Japan and Germany appear to have

borne a share of the burden that exceeded their share of the benefits. This was probably in response to intense lobbying (bargaining) by the United States. This result is consistent with public goods theory where long-term relationships (cooperation) are important.

Recognizing that it is impossible to measure *ex post* equity should refocus the burden sharing debate from outcomes to processes. If we can't measure outcomes to determine equity, we must establish a fair process. If everyone agrees that the process is fair, measuring the outcome becomes unnecessary. For example, the firemen at a local fire station play basketball, ping pong and other competitive games to determine who washes the dishes each day. Because they agree the process is fair, they don't have to track how many times each individual washes the dishes.

As illustrated with Japan and Germany in Operation Desert Storm, contributions can be increased through bargaining. If coalition members value continuing military, political or economic relationships, long run considerations may lead to short run concessions. (Kuenne, 1988; Palmer, 1990) Future research could consider alternative bargaining strategies to find those that create more equitable short run outcomes while maintaining long-run relationships. If the U.S. exploits its bargaining power, it may decrease short run burdens but hurt long run relationships.

Alternatives to bargaining might include matching grants (i.e., the U.S. offers to double the resources contributed by all other coalition members) or extensive networks of formal alliances with carefully specified mechanisms to determine each member's contributions for various contingencies. Different processes have different implications for equity and for the responsibilities and restrictions placed on the U.S. Past attention focused on the NATO/WARSAW Pact confrontation, where U.S. participation was governed by NATO agreements.

Future engagements like Operation Desert Storm are probably more likely than a NATO/WARSAW Pact conflict. There are no agreements between the U.S. and it's allies for these operations. Thus, it is important to establish a procedure, in advance, that will foster equity ⊾ future operations without hurting long term relationships.

APPENDIX

Introduction

This Appendix uses a simple 3-country general-equilibrium model to examine the possible effects of reductions in OPEC oil production capacity on world oil prices and on GDP in industrialized countries. In this stylized framework, Country 1 (e.g., the U.S.) produces both oil (denoted X), and industrial goods (denoted Y). Country 2 (e.g., Japan) only produces industrial goods. Country 3 (e.g., Saudi Arabia or Kuwait) only produces oil. Country 2 relies 100% on foreign oil while Country 1 uses both domestic and imported oil.

Conventional wisdom holds that reductions in oil supplies and the resulting rise in world oil prices will have a more adverse impact on Country 2's economy than that of Country 1. Unfortunately, "foreign oil dependence" is a poor proxy for evaluating the economic consequences of oil supply disruptions. In fact, the relative international competitiveness for countries relying more heavily on imported oil can actually increase as world oil prices increase if they have more energy efficient manufacturing capabilities. Energy efficiency can offset the impact on GDP of heavier dependence on foreign oil. The oil price elasticity of GDP, which measures the percentage change in GDP with respect to the percentage change in oil prices, is the appropriate index for measuring the economic impact of higher world oil prices. The oil price elasticity of GDP incorporates both energy efficiency and foreign oil dependency.

The Model

This analysis uses a general equilibrium model where countries maximize their utility subject to a budget constraint (the country's GDP). Production involves two final goods, industrial goods and oil. Oil is the only input in industrial production; industrial goods are the only input in oil production. Thus, both oil and industrial goods are inputs and final products. Both goods are sold in world markets. All countries face the same world prices (transportation is costless).

Country i's utility is given by a Cobb-Douglas utility function:

$$U_i = U(X_i, Y_i) = X_i^{a_i} Y_i^{b_i} \qquad (i=1,2,3).$$

a_i and b_i are positive constants. X_i denotes Country i's consumption of oil as a final product and Y_i represents its consumption of final industrial goods.

Country i's production of oil is given by:

$$R_i = f(W_i) = T_i W_i^{s_i} \qquad (i = 1, 3).$$

T_i and s_i are positive constants ($0 < s_i < 1$). W_i denotes the amount of industrial goods used in oil production.

Finally, Country i's production of industrial goods is given by:

$$Q_i = g(Z_i) = G_i Z_i^{c_i} \qquad (i = 1, 2).$$

G_i and c_i are positive constants ($0 < c_i < 1$) and Z_i denotes amount of oil used in producing industrial goods. If Country 2's production capacity is more energy efficient than Country 1's, either $c_1 > c_2$, $T_1 > T_2$, or both.

Producers are assumed to maximize profits in both oil and industrial production. Profits are given by:

$$\prod(R_i) = P_x R_i - P_y W_i \qquad (i = 1, 3);$$

$$\prod(Q_i) = P_y Q_i - P_x Z_i \qquad (i = 1, 2).$$

GDP is the sum of the relevant profits:

$$GDP_i = \prod(R_i) + \prod(Q_i) \qquad\qquad (i = 1, 2, 3)$$

Countries are assumed to maximize utility subject to their budget (GDP) constraint.

$$\text{Max } U_i = X_i{}^{a_i} Y_i{}^{b_i}$$

$$\text{s.t. } B_i - P_x X_i - P_y Y_i = 0 \quad \text{where } B_i = GDP_i.$$

For equilibrium, supply and demand must be equal in both the oil and industrial products markets. This is given by:

$$R_1 + R_3 = (X_1 + X_2 + X_3) + (Z_1 + Z_2) \qquad\qquad (1)$$

$$Q_1 + Q_2 = (Y_1 + Y_2 + Y_3) + (W_1 + W_3) \qquad\qquad (2)$$

Equilibrium Solution

To solve for equilibrium in this model, we can find the profit maximizing conditions for oil and industrial production and the utility maximizing conditions for the final products market for each country. These profit and utility maximizing conditions can be expressed in terms of known parameters and the equilibrium prices of the final products. These relationships can be combined with equilibrium conditions for the oil and industrial markets to find the equilibrium prices of oil and industrial goods. Given these prices, we can find specific values for the quantity of oil and industrial goods produced and consumed in each country, and the resulting GDP.

From the first order conditions for profit maximization in the oil-sector, we have:

$$W_i = F(P) = (P_x T_i s_i // P_y)^{1/(1-s_i)};$$

$$R_i = F(P) = T_i (P_x T_i s_i // P_y)^{s_i/(1-s_i)} \qquad\qquad (\text{for } i = 1, 3).$$

From the first order conditions for profit maximization in the industrial-sector, we have:

$$Z_i = F(P) = (P_y G_i c_i / P_x)^{1/(1-c_i)};$$

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$$Q_i = F(P) = G_i \, (P_y \, G_i \, c_i/P_x)^{c_i/(1-c_i)} \qquad \text{(for } i = 1, 2\text{)}.$$

From the first order conditions for utility maximization subject to the Country's budget constraint, we have:

$$X_i = F(P_x) = (B_i \, a_i/ \, P_x \, k_i),$$

$$Y_i = F(P_Y) = (B_i \, b_i/ \, P_Y \, k_i) \qquad \text{(for } i = 1, 2, 3\text{)}$$

where $k_i = (a_i + b_i)$.

Assume that good Y is the numeraire (i.e., $P_y = 1$ and $P_x = P$). P will adjust to ensure equilibrium in both the oil and industrial goods markets. Because there are only two goods in the economy, Walras Law states that equilibrium in one market ensures equilibrium in other market. Thus, the equilibrium price, P^e, can be derived by finding the price that equates total supply and demand in either the oil or industrial goods markets. In other words, P^e can be found by using the profit and utility maximizing conditions from above to solve:

$$R_1 + R_3 = (X_1 + X_2 + X_3) + (Z_1 + Z_2) = F(P^e)$$

Given equilibrium prices, P^e, specific values can be found for R_i, Q_i, X_i, Y_i, W_i, Z_i, $\prod(R_i)$, $\prod(Q_i)$, U_i, and GDP_i.

In this model, the oil price elasticity of GDP is determined by c_i and s_i. Recall that $GDP_i = \prod(R_i) + \prod(Q_i) = (P_x \, R_i - P_y \, W_i) + (P_y \, Q_i - P_x \, Z_i)$. Substituting the equilibrium expressions for R_i, W_i, Q_i and Z_i into this expression and computing elasticity as $(\partial GDP_i/\partial P_x)(P_x/GDP_i)$ yields:

$$\eta_1(P_x) = [1/(1 - s_1)] \prod(R_1)/GDP_1 + [c_1/(c_1 - 1)] \prod(Q_1)/GDP_1$$

$$\eta_2(P_x) = c_2/(c_2 - 1)$$

$$\eta_3(P_x) = 1/(1 - s_3)$$

Thus, in Country 1, the oil price elasticity balances the impacts of higher oil prices on both oil and industrial production. In Countries 2 and 3, with their specialized economies, the oil price elasticity depends completely on

the impact of higher oil prices on industrial production and oil production, respectively.

Simulation Results

The model was used to examine the impact of a 50% reduction in Country 3's oil production on GDP in Countries 1 and 2. Conventional wisdom seems to indicate that "foreign oil dependence" is a good proxy for measuring the relative economic impact of oil price increases across industrialized countries. This exercise was designed to caution against blindly using this proxy by showing that the decrease in Country 2's GDP can be greater than, equal to, or less than the decrease in Country 1's GDP, even though Country 2 is more reliant on imported oil than Country 1. Thus, "foreign oil dependence" is not always a good proxy for measuring the economic impact of oil supply disruptions. The oil price elasticity of GDP is a more appropriate measure.

Oil production is endogenously determined in this model. From above, Country 3's oil production function is $R_3 = T_3 W_3^{s_3}$. In equilibrium, $R_3 = T_3 (P_x T_3 s_3)^{s_3/(1-s_3)}$, so Country 3's oil production can be reduced by decreasing T_3 (recall $0 < s_i < 1$). This is equivalent to an increase in the marginal cost of producing oil in Country 3. This might occur if, for example, some of country 3's oil wells were destroyed.

Parameter values for each of three scenarios are shown in Table A1. All parameter values are shown for scenario 1. Scenarios 2 and 3 only show those parameter values that have changed from scenario 1. The simulation results for each scenario are shown in Table A2. In scenario 1, the percentage decrease in GDP is larger in Country 1. In scenario 2, the percentage decrease in GDP is the same in both countries. Finally, in scenario 3, the percentage decrease in GDP is larger in Country 2. This final scenario

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corresponds to the conventional wisdom that the effect of oil price increases are greater for countries more dependent on foreign oil.

Table 1A: Parameter Values

Country	a_i	b_i	T_i	s_i	P_y	G_i	c_i	G_i	c_i	G_i	c_i
			All Scenarios			Scenario 1		Scenario 2		Scenario 3	
1	.20	.70	8.0	.70	1	2.0	.60	2.0	.60	2.0	.60
2	.20	.70	–	–	1	5.0	.06	3.75	.30	1.7	.60
3	.20	.70	10.0	.70	1	–	–	–	–	–	–

Table 1B: Simulation Results

	Scenario 1		Scenario 2		Scenario 3	
	Country 1	Country 2	Country 1	Country 2	Country 1	Country 2
Oil Price Increase (%)	12	12	12	12	12	12
Oil Price Elasticity of GDP	-0.46	-0.06	-0.41	-0.41	-0.15	-1.50
Initial Foreign Oil Dependence (%)	63	100	59	100	45	100
Foreign Oil Dependence after 50% Supply Cut (%)	36	100	29	100	7	100
Change in Oil Production (%)	31	–	31	–	30	–
Change in Industrial Production (%)	-16	-1	-16	-5	-15	-15
Reduction in GDP (%)	-5.6	-0.7	-4.6	-4.6	-1.6	-15.5
Reduction in Utility (%)	-7	-3	-6	-6	-4	-16

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