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# Defense Spending and the Trade Performance of U.S. Industries

Loren Yager, C. R. Neu

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# Defense Spending and the Trade Performance of U.S. Industries

Loren Yager, C. R. Neu

Prepared for the
Under Secretary of Defense for Policy

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# PREFACE

This report describes the results of a research project aimed at determining whether the sharp increase in defense spending in the late 1970s and early 1980s played a role in the trade performance of U.S. high-technology industries. It describes a mechanism by which defense spending might increase the costs faced by U.S. producers, making it more difficult for them to compete in world trade. It also describes efforts to test this hypothesis.

This research was sponsored by the Under Secretary of Defense for Policy and is a part of the research program of RAND's National Defense Research Institute (NDRI), a federally funded research and development center supported by the Office of the Secretary of Defense and the Joint Staff. The project was conducted as a part of NDRI's International Economic Policy Program.

# SUMMARY

U.S. defense spending increased sharply during the early 1980s, and the increases in spending were particularly rapid in the defense budget categories of procurement and research, development, testing, and evaluation (RDT&E). Purchases from these categories are concentrated in a small number of high-technology industries. During this same period, the U.S. surplus in high-technology trade declined sharply. This study examines the effect of increases in defense spending to determine whether they contributed to the poor trade performance of high-technology industries.

## THE EFFECTS OF DEFENSE SPENDING ON INDUSTRIES

Large increases in defense spending might lead to higher prices for scarce inputs and result in higher costs for certain industries. The industries that are most likely to be affected—"defense-competing" industries—are those that use many of the same scarce inputs as the defense industry, and must compete with the defense industry for those inputs. We focus on labor inputs, since, unlike intermediate products, additional supplies of labor cannot flow easily from foreign sources to the United States. Consequently, domestic—but not foreign—labor costs are likely to increase as U.S. defense spending increases, and this would raise the costs of U.S. defense-competing industries relative to foreign industries. This foreign cost advantage could potentially affect U.S. exports and imports in those industries.

The industries that compete most directly with defense producers for inputs include electronic equipment industries (electronic components; radio, TV, and communication equipment; computers and office machines); machinery industries (metalworking machinery, nonelectrical machinery, special industry machinery); and transportation equipment industries (aircraft and parts, other transportation equipment). These are the industries that should have faced the largest increase in costs as a result of the 1980s defense buildup. Measures of the degree to which these industries compete with defense production for scarce labor inputs are relatively insensitive to a variety of assumptions and data sources included in the calculations.

## MEASURING INDUSTRY TRADE PERFORMANCE

Trade performance measures are developed to highlight the performance of sectors that are exposed to different degrees of competition for scarce inputs. The metrics screen out factors that influence the trade performance of all sectors (exchange rate changes, for example), leaving the influence of sector-specific factors. Industries with good trade performance include plastic and rubber medical supplies, optical instruments, and missiles and space vehicles. The list of industries with the poorest trade performance is headed by iron and steel products and also includes service industry machines, yachts, and fabricated structural metal products.

## ASSOCIATION BETWEEN DEFENSE SPENDING AND TRADE PERFORMANCE

We find no evidence that the increase in defense spending contributed to the poor trade performance of high-technology industries. Calculations using the different trade metrics for a variety of years, or different sources of data in the defense-competing metric, have little effect on the regression results. These results indicate either that defense spending has no effect on trade performance, or that our methods were not sensitive enough to measure the effect.

## CONCLUSIONS

To the extent that increases in defense spending led to a higher budget deficit, they may have contributed to poor trade performance in the form of a higher overall trade deficit by increasing the value of the dollar. But we find no evidence that increased defense spending was particularly damaging to the trade performance of high-technology industries. The most obvious implication is that the poor trade performance of these industries during the mid-1980s was probably caused by factors other than increased defense spending. A second implication is that improvements in the trade performance of high-technology industries—beyond those that might accrue to all industries because of a lower budget deficit—are unlikely to occur as a result of the current decreases in defense spending. This last implication is relevant to the ongoing discussions about appropriate U.S. defense policies. It suggests that a strategy of performing the research and development but delaying large-scale production until needed would not damage U.S. trade performance, at least in economic circumstances similar to those of the early 1980s.

# ACKNOWLEDGMENTS

Several RAND colleagues and others contributed to this research and provided feedback during the briefings on the topic. Gene Gritton and John Koehler provided valuable comments at various stages of the study. The authors would like to thank reviewers David Rubenson and Donald Henry for their comments and suggestions on an earlier draft of this report. All remaining errors are the responsibility of the authors.

# CONTENTS

Appendix

# FIGURES

# TABLES

# 1. INTRODUCTION

There has been a longstanding debate about the effect of defense spending on economic performance, with arguments and evidence provided for both positive and negative effects. Examples of positive effects include the technological spinoffs of defense research and development and training of manpower in less-developed countries. On the other hand, critics point to the diversion of scientific and technical personnel or investment capital as examples of the negative effects of defense spending. It is not surprising that this debate has been renewed as a result of the sharp increase in U.S. defense spending of the late 1970s and early 1980s (see Fig. 1.1).[1]

Recently, the debate has shifted to the effects of defense spending on high-technology industries.[2] One reason for the changing concern is that high-technology industries have become increasingly important among defense suppliers, and therefore are the industries most likely

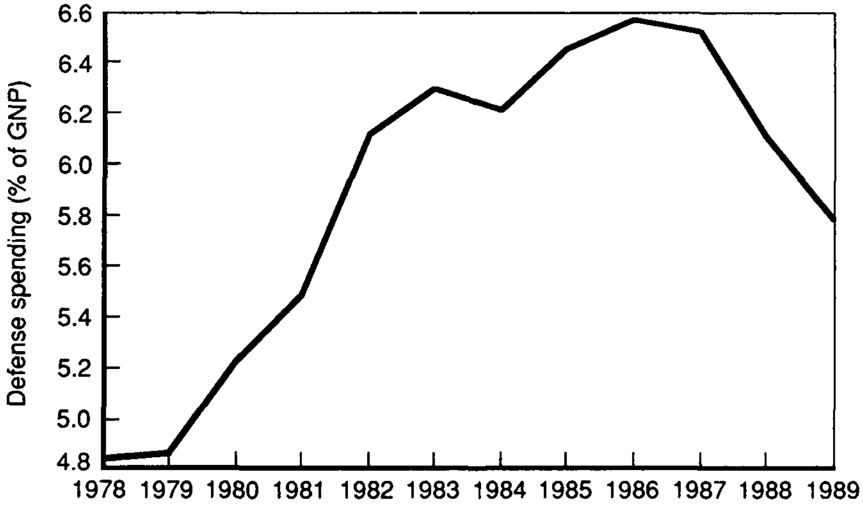

**Fig. 1.1—U.S. Defense Spending as a Percentage of GNP**

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[1] *Economic Report of the President* (1990), Table C-1. In 1982 dollars, defense spending increased from $171.2 billion in 1980 to a peak of $265.2 billion in 1987.

[2] For example, see Browne (1988), p. 5; Dumas (1984), p. 133; Smith (1985); or Markusen (1985), p. 71.

to be directly affected by defense spending.[3] Another reason for focus on "high-tech" is the perceived importance of these industries to the U.S. economy. The industries often described as high-technology industries—electronics, computers, aerospace, communications, etc.—are often considered to be largely responsible for the rapid technological development of the last decades of the twentieth century, in the way that steel and autos were responsible for the industrial development of the mid-twentieth century. Technological progress in high-tech industries is seen by many as offering continued growth opportunities, many of which lead to more general increases in productivity in the workplace and improvements in the standard of living. These gains in productivity and standard of living accrue to the firms or countries responsible for the developments, but U.S. policymakers have expressed concern over the type and the apparent loss of some high-technology markets to foreign producers (see Fig. 1.2).[4] The concern about high-tech industries appears to be a common one in the defense community, where the advances in these industries have given the United States a technological advantage in the production of weapons and other defense systems. The long-term ability of the U.S. economy to finance national security requirements is also a feature of this debate.[5]

The causes of this decline in the trade performance of high-technology industries are poorly understood. Certainly, the strength of the U.S. dollar and other macroeconomic factors during the 1980s had an impact on the trade performance of all sectors. However, it is important to determine whether sector-specific factors contributed to the poor trade performance of U.S. high-technology industries. This report offers one possible explanation: the sharp increase in defense spending.

Defense spending as a percentage of GNP increased sharply from 1980 to 1986, peaking in 1986 at approximately 6.6 percent of GNP. During this same period, the U.S. surplus in high-technology trade declined sharply. After defense spending peaked in 1986 as a share of GNP, the high-technology trade surplus began to recover. These contrasting trends are illustrated in Fig. 1.3.

Of course, the fact that defense spending and the high-technology trade balance exhibit contrasting trends during this period could be

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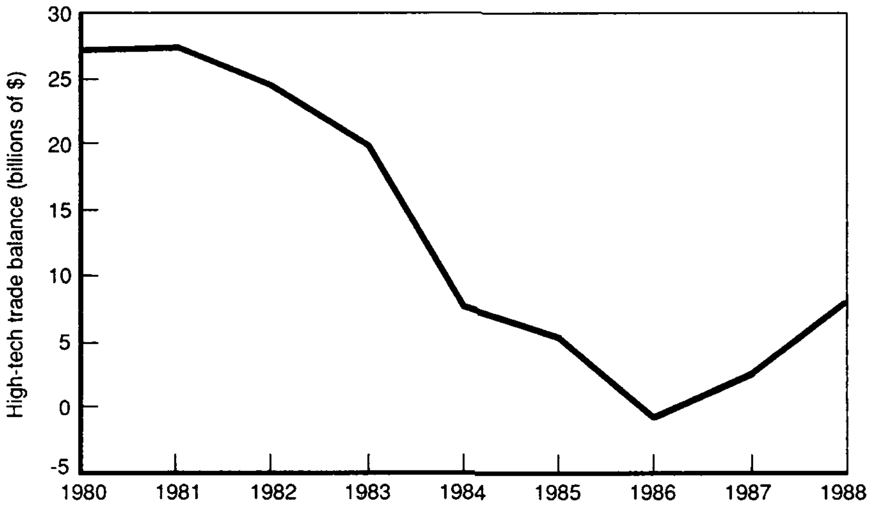
[3] Dumas (1977), p. 20; and Tirman (1984), p. 16.

[4] Defense Science Board (1988).

[5] See, for example, Kennedy (1987); Oden (1988), p. 36; and Sorensen (1988), p. 163.



SOURCE: Davis (1982).

NOTE: Based on the "DOC 3" definition of high-technology industries. DOC 3 identifies high-technology industries using the value of applied research and development funds embodied in both direct and indirect inputs. The total trade (in current dollars) in high-technology products increased from $82 billion in 1980 to $200 billion in 1988.

**Fig. 1.2 —U.S. Trade in High-Technology Products**

purely coincidental. This research will explore whether this negative relationship is more than a chance occurrence.

## PREVIOUS RESEARCH ON DEFENSE SPENDING AND ECONOMIC PERFORMANCE

Studies of defense spending typically identify a particular productive resource and describe how defense spending either enhances or degrades the contribution of this resource to the economy. For example, in less-developed countries, it has been hypothesized that the training provided by military service has a long-term positive effect by enhancing the labor force.[6] The opposite argument has been made for developed countries—that defense production has drawn scarce science

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[6] Benoit (1973), p. 17.

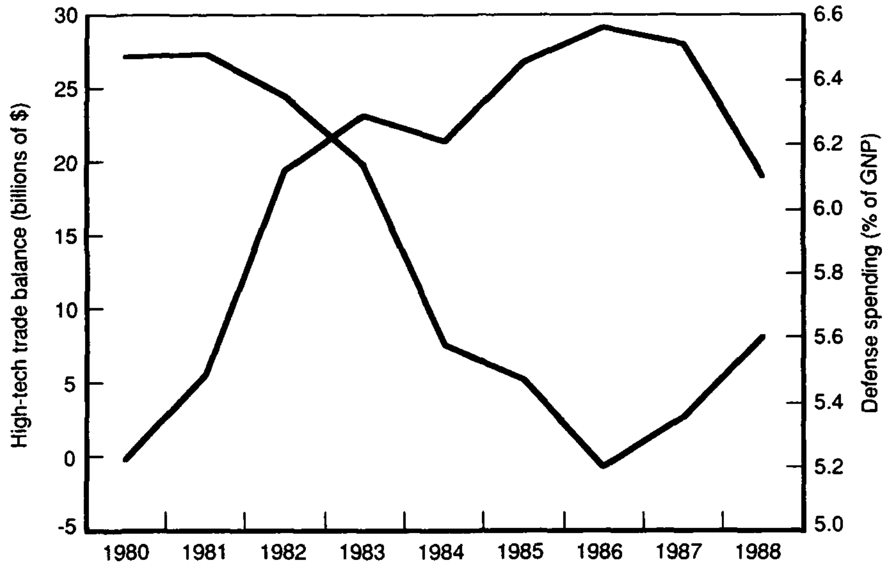

**Fig. 1.3—Contrasting Trends**

and engineering personnel from commercial to defense production,[7] with a negative effect on the commercial industries. Similar arguments can be made about the effect of defense spending on the capital stock.[8] For example, it is possible that capital equipment produced for the military might later be made available at a low cost to commercial users, leading to a larger capital stock than would have developed without the defense spending. On the other hand, defense spending may also divert resources away from investment and thus have a negative impact on the capital stock.

Although it is relatively easy to suggest ways in which defense spending might enhance or degrade productive inputs, it is much more difficult to demonstrate that these changes actually have a measurable effect on some aspect of economic performance. Defense spending for most countries is a relatively small percentage of GNP and, therefore, sensitive measures are necessary to detect the effects of defense spending. In addition, defense spending is made up of a large number of different elements, each of which may have a different effect on economic performance. Finally, other factors affect eco-

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[7] Dumas (1984, 1986).

[8] Smith (1980), p. 20.

nomic performance at any time, so it is difficult to isolate the effect of defense spending.

Two methods that have commonly been used to test for possible effects of defense spending are cross-country comparisons and longitudinal comparisons. Cross-country comparisons are used to test for association between the level of defense spending and economic growth across a number of countries. For example, Emile Benoit found some evidence that in developing countries, defense spending may have had a positive effect on economic growth.[9] Since that time, other researchers have found a negative relationship between defense spending and economic growth in developing countries.[10] Cross-country studies of developed countries have tended to find a negative association, if any, between defense spending and economic growth.[11] However, these cross-country approaches are subject to a variety of problems with regard to attributing the differential performance of nations to defense spending and not to other factors.[12]

Longitudinal analyses have also been used to try to capture the effects of defense spending on economic growth.[13] These methods are designed to evaluate the association between defense spending and economic performance in a single country over a period of years. For example, output might be expected to increase immediately as a result of increases in defense spending, but other effects such as a "training effect" or an "investment effect" may take longer to develop. Therefore, the type of lag that would be expected between defense spending and economic performance depends upon the assumed mechanism by which defense spending will affect the economy. The longitudinal analyses must also isolate the changes in economic performance attributable to defense spending from other factors that may have changed over the period.

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[9] Benoit (1973).

[10] See Deger and Smith (1983), p. 352; or Faini et al. (1984), p. 487.

[11] Cappelen et al. (1984), p. 371; or Smith and Georgiou (1983), p. 15.

[12] Benoit (1973), p. 75, suggests that different levels of bilateral economic aid might be one factor that leads to a "spurious" correlation between defense burden and growth in developing countries. In developed countries, the small number of observations available means that certain countries such as Japan have an overly important influence on the results.

[13] Smith (1980).

## EFFECTS OF DEFENSE SPENDING ON TRADE PERFORMANCE

Most studies of the economic effects of defense spending have focused on aspects of economic performance other than trade performance.[14] However, there are ways in which defense spending might have an effect on trade performance. For example, the increase in government spending for defense purposes could have a macro-level effect on the overall trade deficit, or micro-level effects on particular industries.

### Macro Effects of Defense Spending on Trade Performance

Numerous efforts have been made to assess the relationship between the government deficit and the trade deficit during the 1980s. To the extent that the increase in defense spending contributed to the government budget deficit, these studies also provide insight into the effect of defense spending on trade performance. The link between the budget and the trade deficit has been studied through traditional macro models,[15] regression analyses,[16] and other methods.[17] In general, the findings of these studies support the idea that increases in the government budget deficit contributed to the large trade deficit,[18] although the findings often indicate that the higher level of personal consumption in the United States as compared with other countries was also an important factor.[19]

If increased defense spending is not offset by decreases in other parts of the budget, the resulting higher budget deficit will lead to higher interest rates. Higher interest rates attract capital from abroad, which increases the demand for dollars. This sequence of events led to an increase in the value of the dollar during the early 1980s, raising the price of U.S. products as seen by foreigners and reducing the price of foreign goods to U.S. customers. This certainly contributed to the rapid growth of the trade deficit during this period.

In this sense, the increase in defense spending was a factor in the poor trade performance of the United States, although it was no different in kind from any of the other contributors to the budget

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[14] An exception is Leonard and Passell (1968).

[15] See Plosser (1982) or Hoelscher (1986).

[16] See Bahmani-Oskooee (1989), Abell (1990), or Darrat (1988).

[17] See Zietz and Perberton (1990).

[18] This is not a unanimous view. See Evans (1984).

[19] See Krugman and Baldwin (1987).

deficit. Therefore, the effect of defense spending on trade performance through this mechanism depends on the contribution of defense spending to the budget deficit. Defense spending accounted for the largest on-budget growth during this period, although other components of the budget, such as financing the national debt and various entitlements programs, also grew during this period.[20]

A more substantial influence on the government budget deficit—and therefore the trade deficit—in this framework was the tax cut enacted during the 1982–1984. This tax cut included lower marginal tax rates for individuals, indexing of tax rates, and more generous depreciation schedules for business. It cut revenues by $139 billion in 1984, the first year that the lower marginal tax rates for individuals were fully phased in.[21] This one-year decrease in tax revenues compares with a cumulative real increase in defense spending of $123 billion for the four years from 1981 through 1984 over the 1980 level.[22] Therefore, the increase in defense spending, the tax cut, and the differences between levels of personal consumption in the United States and abroad all appear to have contributed to the higher government deficit and therefore to the poor overall trade performance of the United States during this period.[23]

## Micro Effects of Defense Spending on Trade

Defense spending might also affect trade performance on an industry level, by providing either positive or negative spillovers. For example, research and development (R&D) conducted for the military might contribute to the commercial success of certain firms, and these firms might increase their exports as a result. Case studies have demonstrated positive "spinoffs" of military R&D on commercial products.[24] Another positive spillover of defense spending might be economies of scale realized from higher levels of output. The fact that some industries where defense spending has been concentrated have been among the leading export industries—aerospace and electronics—suggests that defense may have had a positive impact on trade

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[20] Pechman (1982), p. 37.

[21] Pechman (1982), p. 29.

[22] Data on the defense budget are from Pechman (1982), p. 53. Deflators are from the *Economic Report of the President*, 1990, Table C-3.

[23] Both the increase in defense spending and the tax cut would further increase the value of the dollar by raising incomes and consumption in the United States, which would lead to additional purchases of imports.

[24] Nelson (1982).

performance. Unfortunately, it is difficult to assess the effects of these spinoffs beyond the individual examples studied, and there are questions as to whether technological spinoffs or scale economies are as likely from current defense spending as they were in previous decades.

In addition to positive spillovers, it is also possible that certain negative spillovers can be attributed to defense spending. For example, some have claimed that scientists and engineers, once they have been employed on defense projects, are no longer as valuable for commercial production.[25] This could occur because the employees could lose the sense of cost-conciousness that is important to commercial producers. Another type of negative effect on personnel is that defense workers may become overspecialized because of focusing on military specifications that are not relevant in commercial products. These changes in the workforce would imply that certain industries that rely on persons in those occupations might be negatively affected. As in the cases of positive spillovers, it is difficult to gauge the importance of these effects, and it would be difficult to demonstrate the implications for the trade performance of the nation.

However, there is a somewhat different mechanism by which defense spending might affect the performance of industries, and that is by creating shortages of productive inputs. Some authors have argued that the high percentage of scientists and engineers working for defense projects leads to a reduction in employment of those personnel in civilian occupations, and therefore leads to a reduction in civilian innovation.[26] This argument rests on the assumption that the supply of scientists and engineers is somehow fixed, even over the long run. It is more likely, however, that the supply of engineers and other highly trained professionals is limited only by the ability of our schools to train those additional workers, so the constraint is operative only for as long as it takes to train additional scientists and engineers. This constraint would be binding only in periods where there were rapid increases in defense spending, such as the early 1980s. This period offers an opportunity to study the potential effects of these short-term resource constraints.

The methods used in this study combine certain aspects of the cross-country and longitudinal designs. The study is based on a type of cross-sectional analysis, but in this case industries rather than countries are the unit of analysis. Defense spending has a differential im-

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[25] Davis (1986), p. 169.

[26] For example, see Dumas (1984), p. 17.

pact on industries, so it should be possible to compare industries to determine whether there is an association between the effect of defense spending on an industry and the industry trade performance. As in the longitudinal analyses, economic performance is measured at specific points in time, to allow study of the effects of a single large change in defense spending.

## THE THEORY BEHIND THIS RESEARCH

Consider what we might call "defense-competing" industries. These are industries producing civilian goods that use many of the same inputs as industries producing defense goods and therefore compete with defense producers for inputs. The commercial aircraft industry is an example. Commercial and military aircraft producers use many of the same inputs, from production personnel such as machine tool operators, to components such as semiconductor chips. When the price of defense inputs increases, the price of inputs for the commercial aircraft industry would also be expected to increase. Rapid increases in demand for defense products, in combination with a relatively inelastic supply of the productive inputs, would cause wages or prices for defense inputs to increase. This situation would presumably lead to increases in costs for "defense-competing" industries.

Figure 1.4 illustrates the likely consequences of an increase in defense spending. The increase in defense spending leads to an increase in demand for both material and labor inputs. Material inputs are commonly available from both domestic and foreign defense-competing industries. Since most material inputs are traded on the world market, inputs diverted from both domestic and foreign sources are available to help supply the defense demand. Under these conditions, a short supply of an input domestically will likely lead to a short supply abroad. Therefore, increases in defense demand are not likely to increase material prices any more for domestic firms than for foreign firms.

However, competition for labor inputs may be different. In the short run, labor inputs do not easily cross borders for cultural, legal, linguistic, and other reasons. Large increases in defense spending might create pressure for wage increases in certain occupations and therefore increase the costs of defense-competing industries in the United States. Since additional supplies of labor cannot flow from foreign sources to the United States, foreign labor costs are not likely to increase. This would raise the costs of U.S. defense-competing industries relative to foreign industries, creating a foreign cost advantage and potentially lead to a shift in trade patterns.

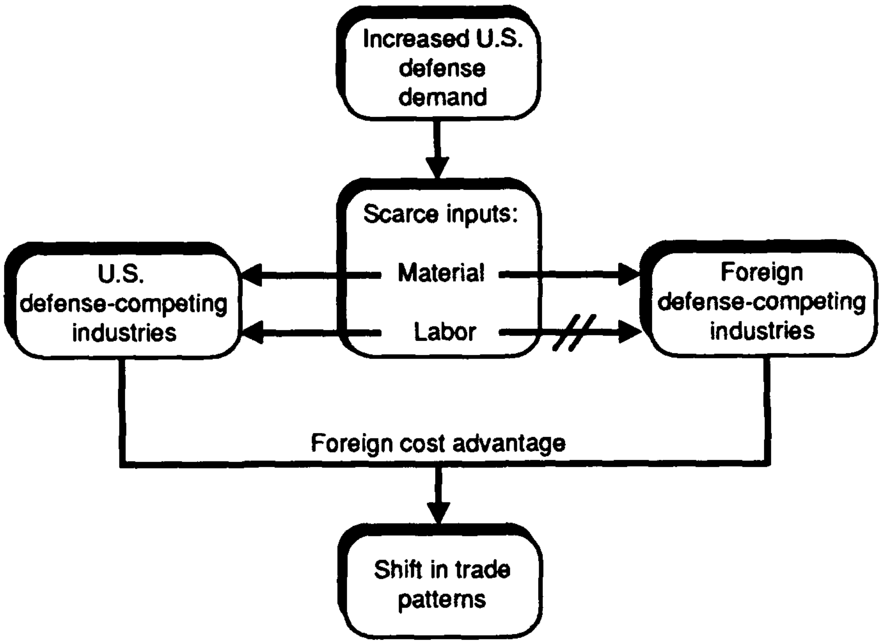

Fig. 1.4—The Theory Behind This Research

To test this theory, it is necessary to compare U.S. industries with their counterparts abroad. The industries that share a large number of scarce labor inputs with defense producers are likely to face the largest increase in costs as a result of the sharp increase in defense demand. These industries would be expected to be at a relatively large disadvantage with respect to foreign producers. Other industries may have little overlap in terms of their labor requirements with defense producers—a low level of "defense-competitiveness"—and therefore are likely to face relatively little cost disadvantage with respect to foreign producers. Therefore, a comparison of the trade performance of defense-competing with nondefense-competing industries might indicate whether the change in defense spending had an impact on industry performance.

It would be useful to be able to test the other effects of defense spending using price and wage data from within the United States. However, a wide variety of other factors will affect the wages and prices within industries, and the defense-spending effect cannot be separated from these other effects. For example, prices may actually be decreasing for many high-technology products because of rapid technological advances,[27] an influence that may be independent of the effect of defense spending. Since it is not possible to factor out those individual influences on industries, a comparison of output prices among U.S. industries could not separate the defense spending effect from the other effects and could lead to inappropriate conclusions. Comparisons of wage changes among occupations in the United States would have similar problems. Using trade performance measures is one way to compare changes in the United States to those occurring abroad.

## The Composition of the Defense Buildup

Because this research measures the differential effects of defense spending on industries, those aspects of defense spending that have the greatest direct impacts on industries are of interest. Virtually all of the research, development, testing and evaluation (RDT&E) and procurement categories generate purchases of equipment or technology directly from private industry. Figure 1.5 shows the share of the U.S. defense budget that is accounted for by the procurement and RDT&E categories and how this share increased from 1980 to 1986.[28] Purchases from these categories are highly concentrated in a few industries such as aerospace, communications equipment, ordnance, and electronics. These industries employ a large number of skilled workers for design and production tasks—skills that may be in short supply during a rapid increase in demand.

The effects on industry of the personnel and operations and maintenance (O&M) spending are more evenly distributed across all industries. Increases in spending for personnel may have some measurable effect on certain broad categories of workers in the labor force but are unlikely to have much effect on specific industries. This is particularly true because the majority of enlistees do not enter the service with specialized skills, and as a result, the supply of these workers is likely to be more elastic. Payment of employees in the personnel account also has an effect on industries through indirect purchases of

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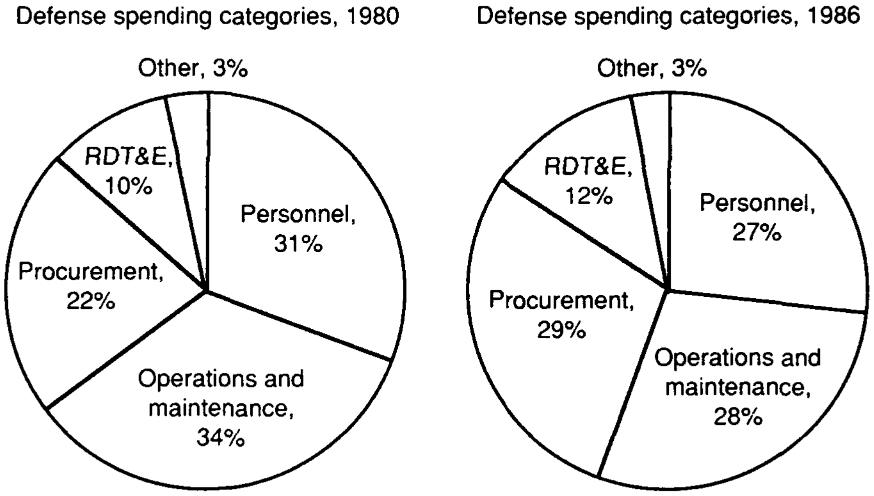
[27] Revised price deflators for computers suggest that computer prices dropped more than fourfold in the ten-year period beginning in 1975, and the broader category of office, computing, and accounting machines dropped by one-half. See Cartwright (1983).

[28] The totals in nominal terms for all categories in 1980 and 1986 were $131 billion and $265 billion, respectively.



SOURCE: U.S. budget.

**Fig. 1.5—Major Defense Spending Categories, 1980 and 1986**

goods and services by those employees and their dependents. However, these indirect purchases are distributed in a less concentrated set of industries than the direct purchases of the DoD, and are unlikely to be substantially different from purchases by workers in other industries.

## The Timing of the Defense Buildup

The longitudinal nature of our research design requires that we identify a period of change in defense spending. Ideally, we would identify a year before any significant change in defense spending occurred and a second year where the change in spending had reached its peak. The peak year should be one in which defense spending was most likely to have led to an increase in costs for scarce defense inputs such as skilled labor. Increases in costs occur when productive inputs, including plant capacity, intermediate products, and in particular skilled labor, are not available in sufficient quantity at current prices and wages. This situation would result from successive increases in defense spending with no "off-years" for industry to catch up.

Defense spending increases from 1980 to 1983 were rapid and continuous in the procurement and RDT&E categories (Fig. 1.6).[29]

After a relatively small increase from 1979 to 1980, the combined spending in procurement and RDT&E demonstrated increasing growth each year through 1983, peaking at a real growth rate of nearly 20 percent. The growth rate for spending in the combined procurement and RDT&E category declined in 1984. A focus on these categories during this period of sharp increases in demand offers the best opportunity to observe the differential effect of changes in defense spending on industry performance. These years of increasing growth offered little opportunity for the industry to catch up. This period is also short enough so that persons who began formal training in these fields as a result of the defense buildup would not have completed their degrees in time to enter the workforce by the end of this period.

For the remainder of this research, the year 1980 will represent the baseline or pre-buildup industry, and the year 1983 will represent the peak year when measurable effects are most likely to occur.

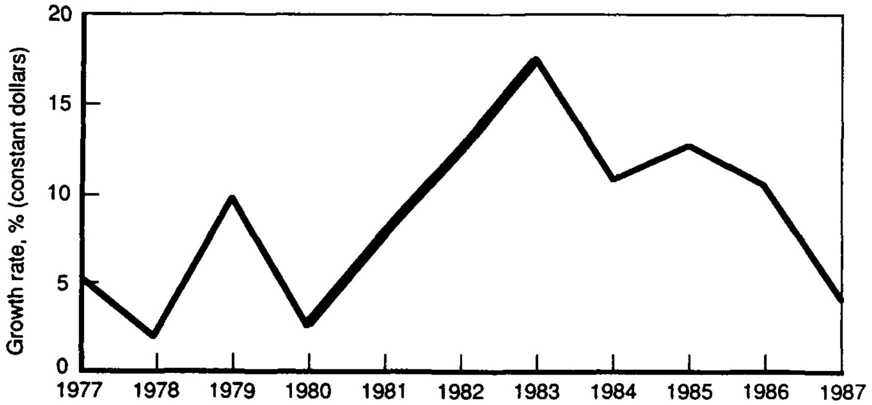


Fig. 1.6—Real Growth Rate of Procurement and RDT&E

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[29] From 1980 to 1983, the outlays in these categories increased from $50.5 billion to $70.5 billion in 1982 dollars.

## RESEARCH APPROACH

The research approach for this project has three major steps, as illustrated in Fig. 1.7.

The first step identifies the defense-competing industries most affected by the buildup in defense spending. In a period of sharply increased defense demand, defense producers will bid up the wages for certain types of workers who are in inelastic supply to increase output to keep up with demand. These increased wages will also increase the costs for defense-competing industries. Industries that use many of the same types of workers as defense producers would be expected to face a large increase in costs, whereas other industries may be relatively unaffected.

To estimate this expected increase in costs for each industry, the increases in procurement and RDT&E outlays from 1980 to 1983 are converted into increases in demand for each of 77 industries. Using both input-output tables and a matrix detailing the number of employees by occupation for each industry, the differential effects of these demand increases on approximately 500 occupational categories are estimated. Using estimates for the elasticity of demand for certain categories of final demand and judgments about the supply elasticity for various occupations, the 77 industries are then ranked according to a metric that represents their expected increase in labor costs.

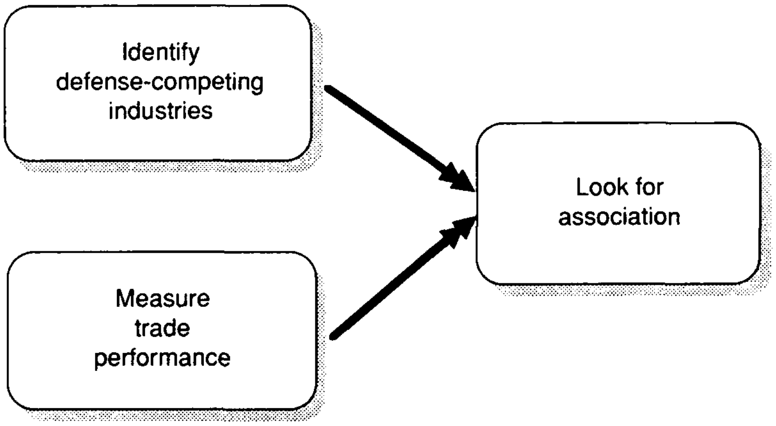

Fig. 1.7—Research Approach

The second step of the research project is to examine the trade performance of U.S. industries. Three measures are developed to reflect the changes that occurred within individual import and export industries. The trade performance measures are designed to be largely insensitive to the factors that influenced overall trade, such as the value of the dollar and differential growth rates in the major countries around the world. The measures are based on rates of growth of imports and exports for three-digit Standard Industrial Classification (SIC) import and export categories. They are also computed from the base period of 1980 through a variety of endpoint years to allow for any potential lagged effects of the defense spending on trade performance.

The third step of the research project involves testing the relationship between the effect of defense spending and the trade performance of industries. A series of analyses determine whether any association exists between the defense-competing and trade performance measures. If defense spending has a negative impact on the trade performance of industries, the results of our research would indicate a negative relationship between the level of defense-competing metric and the trade performance metric. On the other hand, if there is no significant relationship between the trade and defense-competing measures, competition for skilled labor probably did not affect the trade performance of industries. Since the high-technology industries are among the highest defense-competing industries, the strength of this relationship will also indicate whether the poor trade performance of high-tech industries is related to defense spending.

## OVERVIEW OF THE REPORT

The organization of this report follows closely from this research approach. Section 2 describes the methods used to identify defense-competing industries. It includes the methods developed to estimate the added costs that are likely to occur as a result of the defense buildup. Results are provided for a series of calculations that incorporate different data sources and assumptions.

Section 3 describes the trade performance measures and includes a discussion of the criteria that were developed to choose among trade performance measures. The three performance measures that meet these criteria are described and the trade performance results are compared. Trade performance results for a range of years are also included.

Section 4 provides a series of regression results between the defense-competing measures described in Sec. 2 and the trade performance measures described in Sec. 3. Both plots and statistical results are used to describe and test the level of association between the measures. This section also describes the broader assumptions underlying the research.

The final section of this report discusses the findings and their implications.

# 2. IDENTIFYING DEFENSE-COMPETING INDUSTRIES

The effect of defense spending, and especially the direct purchases of the DoD, are not uniformly distributed across all sectors of the economy. Most of the direct purchases are concentrated in industries such as aircraft and electronics. However, the indirect purchases of the DoD are more widely distributed among industries. The U.S. economy is enormously complex, and increased defense demands on one industry may have consequences for other industries even if the DoD buys nothing directly from these other industries. Although defense spending constitutes a major component of the total demand for goods and services in the U.S. economy, it is not so large that its economic consequences are easily observed through general macroeconomic analyses. Neither are macroeconomic concerns usually foremost in the minds of policymakers. More often, policymakers focus their attention on how defense spending affects particular industries or regions. For all of these reasons, it would be useful to develop a general framework for identifying sectors of the U.S. economy where the consequences of changes in defense spending—either up or down—will be most pronounced.

As a step toward such a framework, we have developed the concept of defense-competing industries—industries that compete with defense production in the sense that they use as inputs many of the same scarce resources that are required for defense production. When defense production increases, these resources may be in short supply, their prices may rise, and defense-competing industries may face higher costs. Our aim has been to devise a practical measure of the degree to which various industries compete with defense production and thus a measure of how much the production costs of these industries may be affected by a change in defense spending.

Two considerations are key in defining such a metric. The first is to determine which industries use the same inputs that are needed for defense production. Since not all defense production requires the same set of inputs, the set of defense-competing industries will not be constant through time but will depend on the composition of a particular change in defense spending. A surge in defense spending driven largely by increased funding for exotic weapon systems (the Strategic Defense Initiative, the B-2, etc.) will require different inputs than a major buildup of conventional ground forces (tanks, artillery, etc.).

An industry that may face sharply changed competition from some kinds of defense production may be relatively unaffected by others. This suggests that our metric for defense competitiveness must be flexible enough to reflect the consequences of changes in the composition of defense spending.

A second concern is whether the inputs needed for defense production and for production in potentially defense-competing industries are in limited supply. A particular industry may use many inputs that are also used in defense production. If these inputs are in plentiful supply, or if the supply of these inputs could be expanded easily in response to a relatively minor increase in prices, then an increase in defense spending will probably have only a minor impact on the costs of the industry in question. Similarly, if a small price rise discourages the use of a particular input in other industries, increased defense demand is unlikely to lead to a substantial cost increase for industries that continue using that input. Thus, our metric has to take some account of the scarcity of particular inputs. In the usual economic jargon, we must consider the price elasticity of the supply of and the demand for inputs.[1]

## A LABOR-CONSTRAINED ECONOMY

In this research, we will consider the case of an economy that is constrained principally by the supply of labor. In the short run, of course, economies face additional constraints: the capacity of existing plants, the supply of raw materials, etc. In the longer run, though, these latter constraints can be eased. New factories can be built, intermediate products can be imported, and so on. In the very long run, labor constraints can also be eased. New workers can be trained, immigration laws can be changed, etc. But it seems plausible to postulate that, in the United States at least, labor constraints will be longer lasting than most other constraints. A model based on inelastic supplies of labor may provide a reasonable approximation of what will happen over some middle run—say, five years or so—as a consequence of increased defense spending.

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[1] Price elasticity is a measure of how much the supply of or the demand for a good is affected by a change in its price. Elasticities are expressed as a ratio of percentage changes. If a good has a supply price elasticity of 2, for example, the volume of the good supplied will rise by 2 percent every time the price of the good goes up by 1 percent. Demand for a good with demand price elasticity of -3 will decline by 3 percent for every 1 percent increase in its price. Economists usually speak of "own price elasticities"—the amount that supply or demand of a good changes in response to a change in its own price, and "cross-price elasticities"—the amount that supply or demand changes in response to a change in the price of some other good.

A model based on inelastic labor supplies may be particularly relevant when we are concerned with the consequences of defense spending on patterns of international trade. Many of the inputs required for defense production are traded internationally: electronic components, specialized metals, etc. If increased defense spending strains the domestic supply of such an input, some domestic users of that input will turn to foreign suppliers. If trade is perfectly free—perfect information, no tariffs or export restrictions, negligible shipping costs, etc.—an increase in defense spending will raise prices of traded inputs by the same amount in all countries. Since users of these inputs are equally disadvantaged regardless of location, there is no reason to expect that users in one country will gain a competitive advantage over users in other countries. Since trade is never perfectly free, increases in U.S. defense spending might raise the prices of some inputs more in the United States than abroad. Nevertheless, trade in many commodities and intermediate products is extensive, and the free trade model, particularly with respect to U.S. imports, may be an acceptable approximation of reality. Certainly, the free trade model is more applicable to material inputs than to labor inputs.

## A METRIC FOR "DEFENSE-COMPETING" INDUSTRIES

This subsection describes the metric that has been developed to estimate the increase in costs likely to result from an increase in defense spending. The first element of this model is a set of input-output style, fixed-coefficient production relations. Let $A_{ij}$ denote the amount of good $i$ needed to produce one unit of good $j$. Let $F_i$ denote the final nondefense demand for good $i$ and $D_i$ the final defense demand for good $i$. If $Q_i$ denotes the total production of good $i$, market clearing in goods markets then requires that

$$Q_i = \sum_{i} A_{ij} Q_j + F_i + D_i \tag{1}$$

for each of $n$ goods. In matrix notation,

$$\mathbf{Q} = \mathbf{A}\mathbf{Q} + \mathbf{F} + \mathbf{D} \, . \tag{1a}$$

(Throughout this report, boldfaced letters denote matrices and vectors.) If $(\mathbf{I} - \mathbf{A})$ is nonsingular, Eq. (1a) can be rewritten as

$$\mathbf{Q} = (\mathbf{I} - \mathbf{A})^{-1}(\mathbf{F} + \mathbf{D}) \, .$$

Letting lower-case letters denote changes in the vectors represented by upper-case letters, we have

$$q = (I - A)^{-1}(f + d) . \qquad (1b)$$

The matrix $(I - A)^{-1}$ is the so-called total requirements matrix published regularly by the U.S. Commerce Department as part of its standard input-output exercise. It denotes the total change in the vector of outputs $Q$ necessary to satisfy a change in the vector of final demands $(F + D)$.

Let us further assume that there is a fixed supply of each of $m$ kinds of labor, denoted by $L_i$. Let $B_{ij}$ denote the amount of labor of type $i$ required to produce one unit of good $j$. Labor market clearing requires that

$$\sum_j B_{ij} Q_j = L_i \qquad (2)$$

for each type of labor $L_i$. In matrix notation,

$$BQ = L . \qquad (2a)$$

The U.S. Labor Department occasionally publishes estimates of the matrix $B$, the amounts of various types of labor employed in different industries. Writing Eq. (2a) in different form and remembering that the labor supply vector $L$ is fixed,[2] we have

$$Bq = 0 . \qquad (2b)$$

Substituting (1b) into (2b), we have

$$B(I - A)^{-1}(f + d) = 0 , \qquad (3)$$

which says that any extra labor required to satisfy a change in defense demand, $d$, must be freed by offsetting reductions in nondefense demand, $f$.

For convenience, let us introduce a new matrix

$$C = B(I - A)^{-1}, \qquad (3a)$$

which can be interpreted as a matrix of total labor requirements. We now assume that competition in the economy suffices to keep profits equal to zero.[3] Thus,

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[2] In one set of calculations of this metric, we have assumed that only skilled occupations are in fixed supply. Demand for workers in other occupations may still increase but will not lead to wage increases and therefore have no effect on industry costs.

[3] We could equally well assume that profits are a constant fraction of input costs.

$$p_i = \sum_i C_{ji} W_j \ , \qquad (4)$$

where $P_i$ is the price of good $i$, and $W_j$ is the wage for labor of type $j$. In differential form,

$$p_i = \sum_j C_{ji} W_j \ . \qquad (4a)$$

To complete the model, we assume that the vector of final defense demands, $\boldsymbol{D}$, does not depend on prices, being determined instead by some estimates of "national security requirements." The vector of final nondefense demands, $\boldsymbol{F}$, however, does depend on prices. For simplicity, assume that all cross-price elasticities are zero, such that only the price of good $i$ affects demand for good $i$. Further, we ignore income effects on the vector of nondefense demands.

We are now ready to calculate our metric of defense competitiveness. First, note that an increase in the wage for labor of type $j$ (denoted by $w_j$) will, by Eq. (4a), result in a price increase for good $k$ of $w_j C_{jk}$. This price increase will reduce demand for good $k$ by $w_j C_{jk} f_k$, where

$$f_k = -\partial F_k \ / \ \partial P_k \ .$$

This reduction in final demand for good k in turn implies a reduction in demand for labor of type j, by Eq. (3) of

$$W_j C_{jk}^2 f_k \ . \qquad (5)$$

What is true of industry $k$ will be true of all other industries, and the total decline in demand for labor of type $j$ as a result of a wage increase will be the sum of effects stemming from all industries that use that type of labor. Thus the total change in demand for labor of type $j$ will be

$$\sum_k W_j C_{jk}^2 f_k = \sum_k C_{jk}^2 f_k \ .$$

We know that an increase in demand for labor of type $j$ as a consequence of increased defense spending must be offset by a decline in demand for labor of type $j$ as a consequence of a decline in nondefense demand. The extra labor of type $j$ required by changes $d_k$ in the defense consumption vector will be

$$\sum_k C_{jk} d_k \ .$$

Thus,

$$W_j \sum_k C_{jk}^2 f_k = \sum_k C_{jk} d_k \ ,$$

or

$$W_j = \frac{\sum_k C_{jk} d_k}{\sum_k C_{jk}^2 f_k} \ . \tag{6}$$

Substituting Eq. (6) into Eq. (4a) yields an expression for the change, $p_i$, in the price of good $i$ as a result of changes $d_k$ in defense spending:

$$p_i = \sum_j C_{ji} \frac{\sum_k C_{jk} d_k}{\sum_k C_{jk}^2 f_k} \ . \tag{7}$$

Now note that

$$f_k = -\left( \frac{\partial F_k P_k}{\partial P_k F_k} \right) \frac{F_k}{P_k} = \varepsilon_k \frac{F_k}{P_k} \ , \tag{8}$$

where $\varepsilon_k$ is the negative of the own price elasticity of nondefense final demand for good $k$. (In this formulation, $\varepsilon_k$ will typically be positive.)

So far in the development of this metric, units have not been specified for $F$, $D$, $f$, and $d$. If we choose as units the amounts that can be bought for one dollar in the base period (that is, before any changes in defense demand), the initial price for any good, $P_i$, is equal to one. Using this fact and substituting Eq. (8) into Eq. (7), we have

$$p_i = \sum_j C_{ji} \frac{\sum_k C_{jk} d_k}{\sum_k C_{jk}^2 \varepsilon_k F_k} \ , \tag{9}$$

where the summation in the denominator is over all goods for which $F_k$ is positive.

Because $p_i = 1$ for all $i$, $p_i = P_i$ .

In other words, $p_i$ is the percentage change in the price of good $i$. Therefore,

$$\frac{p_i}{P_i} = \sum_j C_{ji} \frac{\sum_k C_{jk} d_k}{\sum_k C_{jk}^2 \varepsilon_k F_k} \,. \qquad (10)$$

Equation (10) provides the metric we are seeking—an indication of how much the price of a particular good will have to change as a consequence of changed input prices brought about by changes in the vector of defense spending. The more the price of an industry's output rises because of defense-related input price increases, the more directly that industry can be said to compete with defense industries.

## DATA REQUIREMENTS

A goal of this study is to develop a relatively simple, easily applied metric to identify the industries likely to be affected most severely by changes in defense spending. As we shall see, even fairly simple metrics generate significant data and computational requirements. In particular, three factors were considered in developing the desired metric: the level of detail of the data, the timing of data, and computational feasibility. The first two considerations are related to the fact that our metric must be based on routinely available data.[4] As we divide the economy into increasingly specific sectors, the information required for calculating the metric of defense competitiveness increases rapidly. As a result, there is an important data constraint. Although it may be possible to estimate *de novo* requirements or elasticities for a few industries, doing so for the many industries required for a usefully detailed analysis of the effects of defense spending is out of the question. Other data limitations were imposed by the need to be able to convert results from one industry classification system to another. As a result, we were not able to use the most detailed (approximately 500 industry) input-output tables, relying instead on the 77 industry table. However, it was possible to use the full occupational detail of the National Occupational Employment Matrix.[5] This matrix contains estimates of the occupational employment for each of 500 occupations in 265 industries.

A second consideration is that the data are available for the years appropriate to the analysis. Because we are interested in events that

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[4] A detailed description of the data sources is included in App. A.

[5] The employment matrix is produced by the Bureau of Labor Statistics, U.S. Department of Labor. Information for the matrix is collected by the BLS in cooperation with state employment agencies.

occurred between five and ten years ago, most of the statistical data required are available by this time. For example, the 1980 and 1983 defense budget data and input-output tables are all available. On the other hand, the National Occupational Employment Matrix is produced only periodically, and in this case the 1986 tables were the best available to represent the employment patterns in 1983. Available estimates of final demand elasticities represent a number of different time periods.[6]

An additional concern is computational feasibility. Despite advances in computing power, some kinds of detailed economic analyses are still not computationally feasible. The ideal approach to calculating the effects of defense spending on various sectors of the economy is general equilibrium analysis. This type of analysis incorporates the effects of every change in every industry on every other industry and on the incomes and spending of consumers. Unfortunately, general equilibrium models of the economy typically do not have analytic solutions. These models can be solved only by very demanding numerical techniques. Although so-called computable general equilibrium models have been applied to some real-world policy questions, the computational requirements of models with enough detail for our purposes are beyond the resources available for this study. More important, it seems unlikely that the advantages of using these ideal models are sufficient to justify the costs of implementing them.

## CALCULATING THE METRIC

Annual defense budgets provide information on changing budget levels for specific defense programs. To make this information suitable for further analysis, it is necessary to convert changes in spending on specific defense programs into changes in defense demand for the output of particular industries. This conversion is accomplished through the use of the defense translator tables, represented by the first "filter" in Fig. 2.1.[7] These translator tables are produced for the Office of the Secretary of Defense as a major component of the Defense Economic Impact Modeling System.[8] The tables divide each of the spending categories of the defense budget into one of approximately 400 SIC categories. These demand increases for each budget category are then added to produce direct demand increases for each

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[6] Results were calculated for a range of elasticity estimates as part of the sensitivity analysis.

[7] Appendix B provides the details of the calculations.

[8] Examples of these tables are provided in App. A.

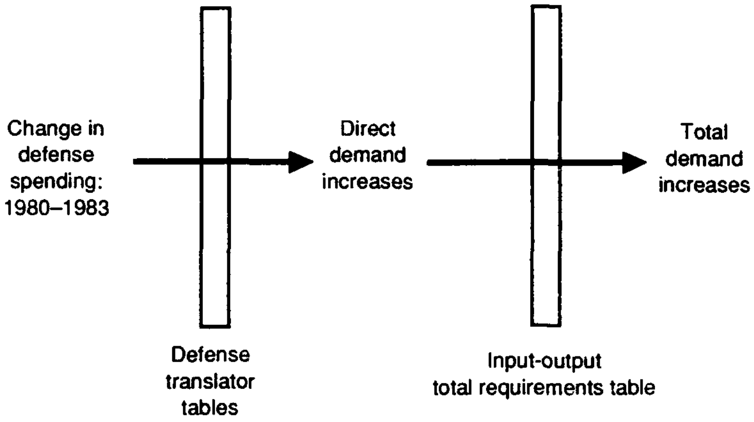

**Fig. 2.1—Estimating Demand Increases**

of 400 SIC industries. These direct demand increases indicate the additional direct purchases in each industry generated by industry sales to the Defense Department from 1980 to 1983. These calculations produce the values $d_k$ in Eq. (10), the increase in output that results from defense spending for each of 77 input-output industries.

The second filter in Fig. 2.1 indicates that the total requirements input-output table is used to calculate the total (direct and indirect) demand increases that result from increased defense purchases. The total demand increases include the additional purchases generated by the purchases of the Department of Defense. These indirect purchases might include industry spending on inputs such as machinery, office equipment, and intermediate materials required to fulfill the direct requirements. In the terms of Eq. (1b), this is multiplying the vector of changes in defense spending by the total requirements matrix $(\boldsymbol{I} - \boldsymbol{A})^{-1}$.

The results of this first round of calculations identify the industries that are likely to experience the largest increases in demand as a result of the increase in defense spending.

The first filter represented in Fig. 2.2 is the labor requirements matrix (matrix $\boldsymbol{B}$ in Eq. (2a)). This matrix converts the increases in industry demand into increases in demand for particular kinds of labor. The intermediate result is the number of additional workers in each of approximately 500 occupations that will be necessary to meet

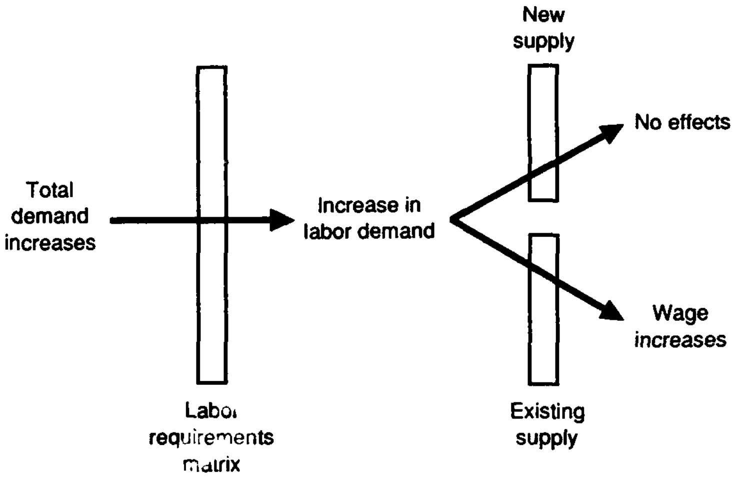

Fig. 2.2—Estimating Wage Increases

the additional demand generated by the increase in defense spending. This intermediate result is represented by the numerator $\sum C_{jk}d_k$ of the fraction in Eq. (10).

However, as indicated on the right side of Fig. 2.2, the wage increases that result from the increases in occupational demand depend on the type of occupation. Since supply elasticities for each of the 500 occupations are not available, we divide the occupations into groups with infinitely elastic or completely inelastic supply. We assume infinitely elastic supply for those occupational groups where entry into the occupation is not limited by a specific skill or educational requirement. For those occupations where entry is limited by some skill or educational requirement,[9] the increase in demand is expected to lead to competition for a limited supply of workers, and wage increases are likely.

The extent of the wage increases required to draw the necessary number of workers from production for civilian final demand is also calculated. These increases depend upon the number of those work-

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[9] The methods used to identify the supply-constrained occupations are described in detail in App. A. The list of supply-constrained occupations is provided in Table A.7.

ers in civil production and the characteristics of demand for their output. If a large number of workers are needed and only a few are employed in nondefense industries, this will lead to competition for these workers and a large increase in wages. The calculations also incorporate elasticities of final demand. If the workers required for defense production are employed in industries characterized by inelastic demand, larger price—and therefore wage—increases would be required to reduce demand for this industry output and free up the necessary labor. This result is represented in Eq. (10) as the fraction

$$\frac{\sum_k C_{jk} d_k}{\sum_k C_{jk}^2 \varepsilon_k F_k} .$$

The final step in estimating the defense-competing measure involves a summation of the various wage increases within each of the 77 input-output industries weighted by the number of workers within each industry. Figure 2.3 illustrates these steps. Both the labor requirements matrix and the input-output tables are necessary, since the defense-competing metric measures the increased costs resulting from all wage increases, including those that result from the direct and indirect demand increases of defense spending. These steps are accomplished by the $\sum C_{ji}$ component of Eq. (10).

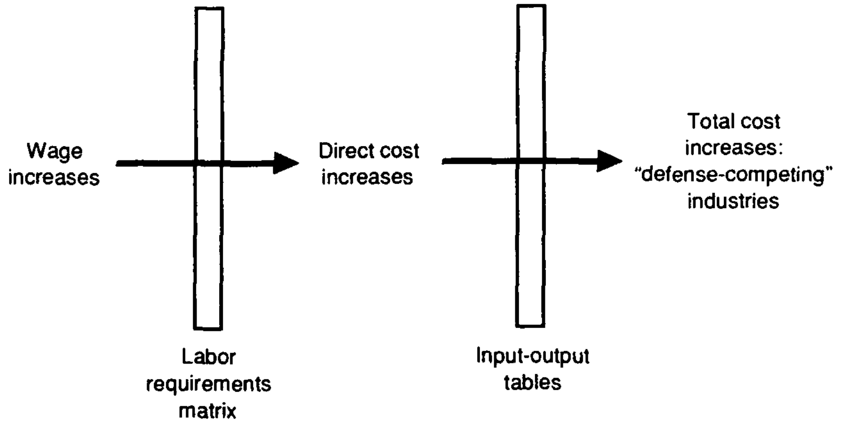

Fig. 2.3—Identifying Defense-Competing Industries

## RESULTS OF THE CALCULATIONS

Table 2.1 ranks industries based on the level of the defense-competing metric. These calculations show that the electronic components industry is the one that should have faced the largest percentage increase in labor costs as a result of the 1980s defense buildup. Other industries that appear at the top of the list include metalworking machinery, nonelectrical machinery, and aircraft and parts.

The numbers in the first column are the levels of the defense-competing metric. These metric values are proportional to the percentage increase in costs that are expected as a result of higher defense spending. For example, the electronic components industry with a metric value of 6.66 should have had twice the increase in costs from the increase in defense spending as the metal containers industry, which had a metric of 3.34. However, this measure is only a reflection of expected increases resulting from defense spending. A wide variety of other influences may have affected prices in these industries and are not reflected in this metric.

Although there is no clear cutoff between defense-competing and nondefense-competing industries, the range of the defense-competing metric from 0.3 to 6.6 does indicate that the increase in costs from defense spending was not evenly distributed across industries.

The industries at the top of the list are concentrated in a small number of sectors, including those related to electronics, transportation, and machinery. Many of these industries are popularly thought of as high-tech industries. Electronics and aircraft industries also appear at the top of the industries identified as high-tech by the U.S. Department of Commerce based on embodied R&D.[10] Most of the machinery industries fall in an intermediate range based on the Department of Commerce definition.

Another comment on the results is that these are not the same industries that experienced the greatest increases in total demand as a result of the increase in defense spending. Service industries and primary industries were among those that were expected to experience substantially increased demand from defense spending. Table 2.2 lists the industries ranked by the expected increase in total demand.

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[10] A direct comparison of the listings is not possible since the Commerce list is based on a National Science Foundation classification system (see Davis, 1982).

## Table 2.1

## Defense-Competing Industries

| Metric | Industry Title | Metric | Industry Title |
|---|---|---|---|
| 6.66 | Electronic components | 1.99 | Plastics and synthetic materials |
| 6.56 | Metalworking machinery | 1.96 | Repair and maintenance construction |
| 5.88 | Miscellaneous nonelectrical machinery | 1.95 | Business services |
| 5.46 | Aircraft and parts | 1.92 | Paperboard containers |
| 5.03 | Radio, TV, and communications equipment | 1.89 | Paints and allied products |
| 5.02 | Other transportation equipment | 1.85 | Paper and paper products |
| 4.91 | Special industry machinery | 1.84 | Glass and glass products |
| 4.86 | Electric industrial machines | 1.81 | Wood containers |
| 4.69 | Other fabricated metal products | 1.80 | Chemicals and chemical products |
| 4.40 | Computers and office machines | 1.77 | Miscellaneous textile goods |
| 4.22 | Materials handling machinery | 1.77 | Drugs |
| 4.17 | Primary nonferrous metals manufacturing | 1.72 | Lumber and wood products |
| 4.16 | General industrial machinery | 1.71 | Printing and publishing |
| 4.02 | Service industry machines | 1.68 | Footwear and other leather |
| 3.94 | Scientific and controlling instruments | 1.66 | Fabrics, yarn, and thread |
| 3.92 | Miscellaneous electrical machinery | 1.63 | Stone and clay products |
| 3.91 | Electric lighting and wiring | 1.62 | Auto repair |
| 3.91 | Farm and garden machinery | 1.59 | New construction |
| 3.87 | Construction and mining machinery | 1.48 | Miscellaneous fabricated textile products |
| 3.86 | Heating, plumbing, and fabricated metal products | 1.47 | Coal mining |
| 3.76 | Screw machine products, stampings | 1.40 | Transportation and warehousing |
| 3.75 | Engines and turbines | 1.39 | Radio and TV broadcasting |
| 3.46 | Iron and ferroalloy ores mining | 1.29 | Health and educational services |
| 3.37 | Nonferrous metals ores mining | 1.28 | Private electric, gas, sanitary services |
| 3.35 | Miscellaneous. manufacturing | 1.24 | Communications, except radio, TV |
| 3.34 | Metal containers | 1.21 | Leather tanning and finishing |
| 3.31 | Ordnance and accessories | 1.20 | Apparel |
| 3.31 | Household appliances | 1.19 | Food and kindred products |
| 3.28 | Optical and photographic equipment | 1.18 | Chemical and fertilizer mining |
| 3.19 | Primary iron and steel manufacturing | 0.94 | Petroleum refining and related |
| 3.06 | Stone and clay mining | 0.89 | Eating and drinking places |
| 2.90 | Motor vehicles and accessories | 0.88 | Amusements |
| 2.31 | Other furniture and fixtures | 0.87 | Tobacco manufactures |
| 2.28 | Rubber and miscellaneous plastics | 0.87 | Livestock and livestock products |
| 2.11 | Household furniture | | |

## Table 2.1.—continued

| Metric | Industry Title | Metric | Industry Title |
|---|---|---|---|
| 0.85 | Forestry and fishery products | 0.72 | Other agricultural products |
| 0.78 | Hotels and personal services | 0.69 | Finance and insurance |
| 0.74 | Crude petroleum and natural gas | 0.63 | Wholesale and retail trade |
| 0.73 | Agricultural services | 0.34 | Real estate and rental |

## Table 2.2

## Total Increases in Demand as a Result of Defense Spending (1980–1983)

| Increase in Demand $M | Industry | Increase in Demand $M | Industry |
|---|---|---|---|
| 13,826 | Radio, TV, and communications equipment | 1,661 | Metalworking machinery |
| 12,124 | Aircraft and parts | 1,650 | Crude petroleum and natural gas |
| 6,922 | Other transportation equipment | 1,632 | Petroleum refining and related |
| 5,787 | Ordnance and accessories | 1,188 | Finance and insurance |
| 5,101 | Electronic components | 1,094 | Other fabricated metal products |
| 4,328 | Business services | 1,059 | Engines and turbines |
| 3,461 | Primary nonferrous metals manufacturing | 934 | Repair and maintenance construction |
| 3,262 | Wholesale and retail trade | 925 | Eating and drinking places |
| 3,057 | Computers and office machines | 779 | General industrial machinery |
| 2,830 | Primary iron and steel manufacturing | 733 | Optical and photographic equipment |
| 2,777 | Private electric, gas, sanitary services | 715 | Paper and paper products |
| 2,756 | Electric industrial machines | 699 | Heating, plumbing, and fabricated metal products |
| 2,522 | Scientific and controlling instruments | 678 | Lumber and wood products |
| 2,351 | Transportation and warehousing | 674 | Communications, except radio, TV |
| 2,018 | Real estate and rental | 656 | Hotels and personal services |
| 1,945 | Chemicals and chemical products | 504 | Materials handling machinery |
| 1,899 | Rubber and miscellaneous plastics | 488 | Stone and clay products |
| 1,811 | Motor vehicles and accessories | 401 | Food and kindred products |

**Table 2.2—continued**

| Increase in Demand $M | Industry | Increase in Demand $M | Industry |
|---|---|---|---|
| 392 | Auto repair | 93 | New construction |
| 380 | Electric lighting and wiring | 83 | Miscellaneous fabricated textile products |
| 353 | Fabrics, yarn, and thread | 71 | Forestry and fishery products |
| 346 | Coal mining | 67 | Miscellaneous electrical machinery |
| 301 | Paperboard containers | 67 | Stone and clay mining |
| 235 | Glass and glass products | 58 | Household appliances |
| 212 | Nonferrous metals ores mining | 5 | Apparel |
| 181 | Construction and mining machinery | 54 | Chemical and fertilizer mining |
| 172 | *Radio and* TV broadcasting | 54 | Other furniture and fixtures |
| 163 | Miscellaneous textile goods | 53 | Metal containers |
| 151 | Paints and allied products | 49 | Agricultural services |
| 145 | Drugs | 41 | Farm and garden machinery |
| 144 | Miscellaneous manufacturing | 18 | Wood containers |
| 127 | Household furniture | 8 | Footwear and other leather |
| 126 | Iron and ferroalloy ores mining | 4 | Leather tanning and finishing |
| 124 | Amusements | 0 | Tobacco manufactures |
| 119 | Other agricultural products | (228) | Special industry machinery |
| 118 | Livestock and livestock products | (548) | Service industry machines |

Our calculations suggest that these industries do not compete with defense producers for scarce workers to the same extent as the high-tech and machinery industries.

Additional insight into the types of occupations that are most responsible for the increased labor costs of the defense-competing industries is provided in Table 2.3. This is an intermediate result of the calculations, listing the occupations that are likely to have had the greatest wage increases as a result of defense spending. The figures in the left

## Table 2.3

## Model Effects on Occupations

| Effect | Occupational Title |
|---|---|
| 3.95 | Nuclear engineers |
| 3.63 | Heating equipment setters and set-up operators, metal and plastic |
| 3.49 | Soldering and brazing machine operators and setters |
| 3.47 | Nonelectric plating machine operators and tenders, setters and set-up operators, metal and plastic |
| 3.28 | Mining engineers, including mine safety engineers |
| 3.02 | Electric plating machine operators and tenders, setters, and set-up operators, metal and plastic |
| 2.23 | Programmers, numerical, tool, and process control |
| 2.02 | Electronics repairers, commercial and industrial equipment |
| 1.97 | Aircraft engine specialists |
| 1.94 | All other printing press setters and set-up operators |
| 1.88 | Urban and regional planners |
| 1.55 | Aircraft assemblers, precision |
| 1.54 | Metallurgists and metal, ceramic, and material engineers |
| 1.51 | Electromechanical equipment assemblers, precision |
| 1.48 | Ship engineers |
| 1.20 | Physicists and astronomers |
| 1.19 | Industrial engineers, except safety engineers |
| 1.15 | Punching machine setters and set-up operators, metal and plastic |
| 1.10 | Metal molding machine operators and tenders, setters and set-up operators |
| 1.08 | All other physical scientists |
| 1.08 | Judges, magistrates, and other judicial workers |
| 1.03 | Economists |
| 1.01 | Shipfitters |
| 1.00 | All other life scientists |
| .97 | All other engineers |
| .94 | Screen printing machine setters and set-up operators |
| .92 | Architects, except landscape and marine |
| .90 | Mechanical engineers |
| .83 | Lathe machine tool setters and set-up operators, metal and plastic |
| .83 | Construction and building inspectors |
| .83 | Operations and systems researchers |
| .81 | Surveyors |
| .80 | Fitters, structural metal, precision |
| .80 | Machine builders and other precision machine assemblers |
| .80 | Management analysts |
| .78 | Civil engineers, including traffic engineers |
| .77 | Biological scientists |
| .75 | Librarians, professional |
| .75 | Electronic semiconductor processors |
| .74 | Teachers, secondary school |
| .73 | Captains and pilots, ship |
| .72 | Drilling machine tool setters and set-up operators, metal and plastic |
| .72 | Grinding machine setters and set-up operators, metal and plastic |

**Table 2.3—continued**

| Impact | Occupational Title |
|---|---|
| .70 | Aircraft mechanics |
| .68 | Counselors |
| .66 | Education administrators |
| .64 | All other precision metal workers |
| .64 | Electrical and electronic technicians/technologists |
| .63 | Mathematicians and all other mathematical scientists |
| .62 | Real estate appraisers |
| .62 | All other electrical and electronic equipment mechanics, installers, and repairers |

column are changes in the shadow price for occupations. Large changes in shadow prices for occupations are created by a combination of increased demand due to defense purchases, and limited potential supply of those workers among the nondefense employers. Numerous production and engineering occupations appear at the top of the list.[11]

This listing of occupations indicates why the high-technology and machinery industries were among the defense-competing industries. The increase in defense spending generated additional demand for certain specialized skills, and there are a limited number of nondefense industries where these workers are employed.[12] For example, nuclear engineers are at the top of the list in terms of the effects of defense spending. Defense spending is likely to increase the demand for nuclear engineers, but an equally important factor is that there is not a large number of nuclear engineers in production for final demand. As a result, it is difficult to squeeze those workers out of civilian employment, and wages are likely to increase significantly.

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[11] This change in the shadow price for occupation $j$ is given by the fraction from Eq. (10).

$$\frac{\sum_k C_{jk} d_k}{\sum_k C_{jk}^2 \epsilon_k F_k} .$$

[12] The fact that the defense-competing industries are overwhelmingly producers of intermediate goods may be related to the assumption of fixed production coefficients. This is further discussed in the final section of the report.

## SENSITIVITY ANALYSIS OF THE RESULTS

Our calculation of the defense-competing metric rests on a number of assumptions and on data from a variety of sources. In some cases, we have no alternative to these assumptions and data sources; whatever their shortcomings, they are probably the best we can do.[13] In other cases, though, there are alternatives, and we have explored the implications of using these alternative assumptions and data sources in our calculations. In particular, we have examined the consequences of alternative treatments of labor supply and the elasticity of final demand.

### Comparisons of the Results Using Various Elasticity Sources

The model used in this analysis assumes a fixed supply of skilled workers within certain occupations. Therefore, the extra labor that is required to satisfy the increase in defense demand must be made available by offsetting reductions in nondefense final demand. These reductions in final demand are based on the assumption that certain events occur as a result of defense spending. The increase in spending generates additional demand for labor, some of which is limited in supply, and wages increase for these occupations. Industries that rely on those occupations face an increase in costs and, therefore, prices will also increase. However, the price increases will have different effects depending on the elasticities of demand. Where demand elasticities are low, significant increases in costs are necessary to reduce demand and release workers for defense production. On the other hand, if the elasticity of demand for certain industries' output is high, numerous workers will be released as a result of small wage increases.

To incorporate final demand elasticities into these calculations, elasticity estimates were necessary for each of 77 input-output industries. The input-output tables divide final demand into the following four categories:

1. Personal consumption expenditures,
2. Gross private fixed investment,
3. Exports, and
4. Government expenditures.

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[13] For example, there is no practical alternative to using the input-output tables and labor requirements table. Neither is there any real alternative to accepting the assumptions such as fixed coefficient production and constant returns to scale that underlie these tables.

Estimates of personal consumption elasticities were available from two sources.[14] Although the estimates for certain industries showed substantial variation, the effects of incorporating alternative demand elasticity sources on the estimates of the defense-competing metric were small. Figure 2.4 is a scatterplot of the defense-competing metric computed with the two different personal consumption elasticities. Each point represents one industry. The strong linear relationship indicates that there is no significant difference between the results. The correlation coefficient is shown in the upper left of the figure.

Demand elasticity estimates for government purchases were not available in the literature, so an additional set of sensitivity tests was performed on a range of plausible elasticity values. In the first case, all government purchases were assumed to be completely inelastic (an elasticity of zero). The second set of results is based on unitary government purchase elasticities (elasticities of negative one). These first two estimates of government purchase elasticities were chosen because they represent plausible upper and lower bounds of elasticity estimates. In the first case, the government has a set of requirements but no budget constraint, and in the second case, the government purchases are bound by a rigid budget constraint. The final set of re-

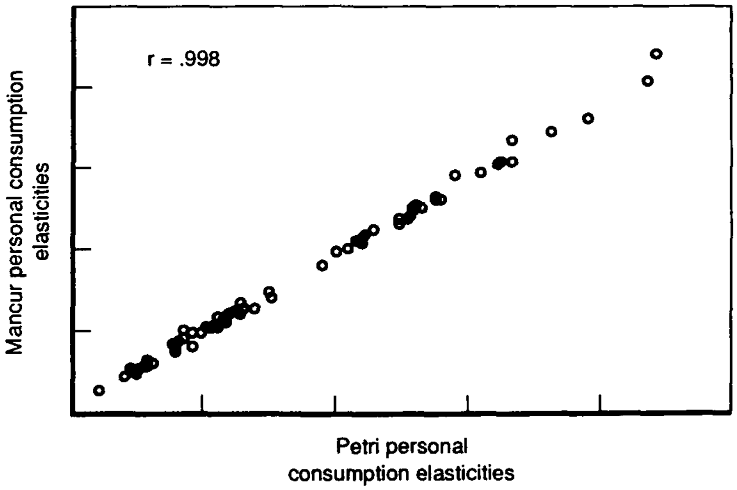

Fig. 2.4—Scatterplot Across Personal Consumption Elasticities

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[14] Mansur and Whalley (1984); and Petri (1984).

sults was based on a combination of zero and unit elasticities, for example, with defense purchases and medical care with zero elasticities (determined by requirements), and local government expenditures with unit elasticities (budget constrained).

The plot matrix in Fig. 2.5 illustrates the effect of these alternative estimates of government purchase elasticities on the results of the defense-competing metric. The scatterplots indicate that the metric results are insensitive to assumptions about the elasticity of demand for government purchases. For example, the upper left plot indicates that there is virtually no difference in the industry values of the defense-competing metric when calculated with government demand elasticities of negative one compared with government demand elasticities of zero.

These comparisons demonstrate that the various final demand elasticities that are incorporated into the calculations do not have a large effect on the values of the defense-competing metric.

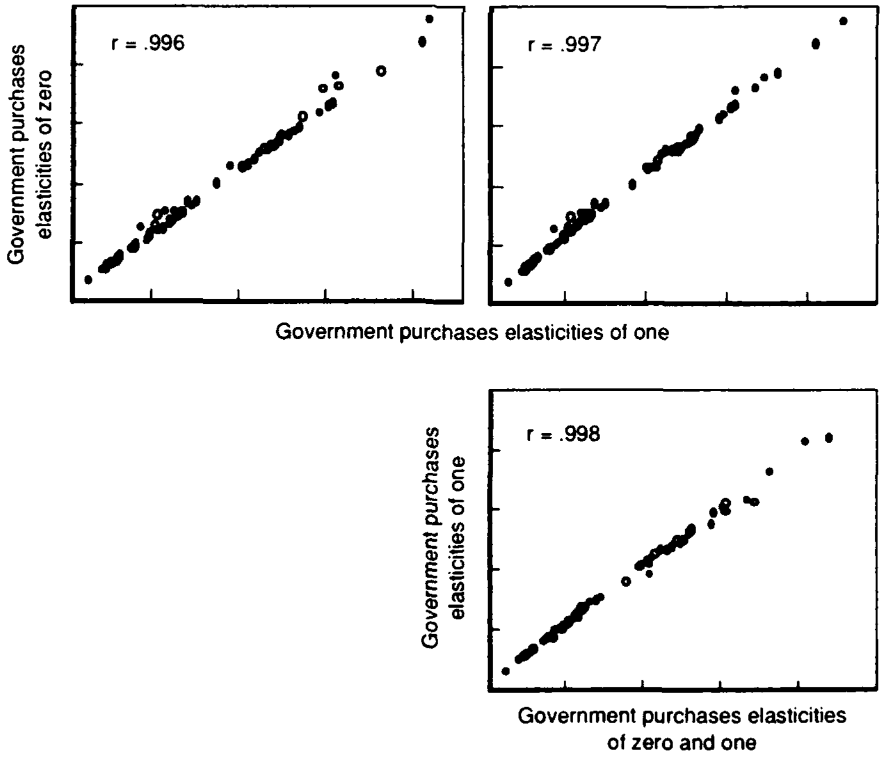

Fig. 2.5—Scatterplot Across Government Purchases Elasticities

## Comparisons of the All-Occupations and Supply-Constrained Occupations Results

Another assumption of this model is that growth in some parts of the labor force is severely limited in the short run. This assumption is embodied in the model as supply elasticities of zero for certain labor occupations. The occupations characterized by inelastic supply were identified using the *Occupational Outlook Handbook*,[15] which describes the qualifications necessary for most of the occupations included in the research.[16] The *Handbook* has detailed descriptions of most of the occupations used in the calculations, and each of these descriptions includes a section on "training, other qualifications, and advancement." To determine which occupations might be realistically described as having zero elasticity in the short run, three specific criteria were used to identify those jobs that might have a low elasticity. Occupations were selected that mentioned a specific educational, experience, or licensing requirement that might be expected to limit entry into the occupation.

Because of the lack of specific information about certain occupations, and the lack of precision in the criteria, there is substantial uncertainty introduced by this choice of occupations. As an alternative, we calculated results under the assumption that all the occupations were supply-constrained. Figure 2.6 indicates that there is a relatively strong positive relationship between the defense-competing metric results calculated based on the assumption that all occupations are supply-constrained and the metric results calculated with only certain occupations assumed to be supply-constrained. The plots show significant differences for some industries. Points that lie below the point cloud indicate industries that have a significantly higher value of the defense-competing metric using all occupations. These would include industries that employ significant numbers of workers in occupations affected by defense spending, but that are not considered supply-constrained. Points that lie above the point cloud indicate industries that have a higher defense-competing metric based on calculations using only occupations that are considered supply-constrained.

One particular outlier above the center of the point cloud is visible in Fig. 2.6: Ordnance and accessories (I-O category 13). This industry appears to rely heavily on occupations that were identified as supply-

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[15] U.S. Department of Labor (1986).

[16] Appendix A describes the selection criteria and provides a listing of the supply-constrained occupations.

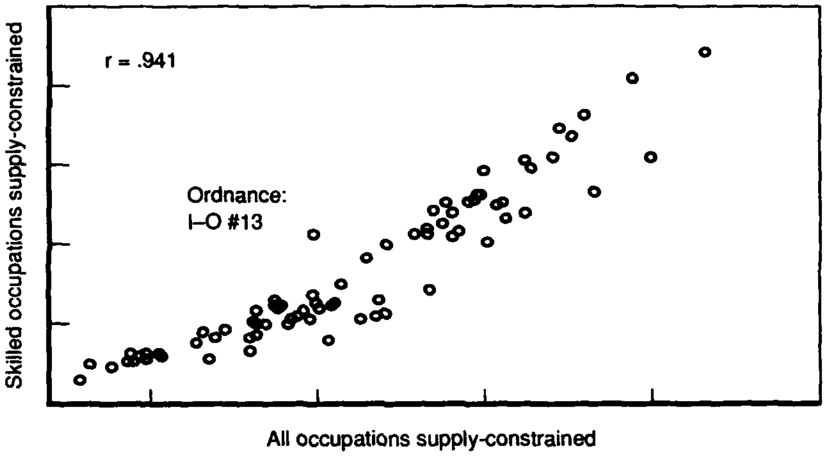

Fig. 2.6—Scatterplot Across Labor Supply Assumption

constrained and therefore has a relatively higher metric using the subset of occupations.

## Comparisons Using Regression Analysis

The rank-order correlation between the defense-competing metric computed with all occupations supply-constrained and the metric with only skilled occupations assumed to be supply-constrained was significantly higher than the linear correlation, suggesting a nonlinear relationship between the variables. The plot also appears to suggest a curvilinear relationship. We regressed the all-occupations metric (all occs.) on the supply-constrained occupations metric (s-c-occs.). As indicated by the regression results reported in Table 2.4, the all-occupations metric is an excellent predictor of supply-constrained metric, with a highly significant t-ratio of over 20.

Figure 2.7 is a residual plot for the regression analysis. As expected from the original graphs, the residual shows some evidence of a curvilinear relationship.

To capture this curvilinear relationship, a squared term (sq_all occs.) is incorporated into the following regression (Table 2.5). The squared term is also highly significant, with a t-ratio of over 4. The residual

## Table 2.4

## Regression of *All-Occupations* Metric and Supply-Constrained Occupations Metric

Dependent variable is: S-C-OCCS

$R^2$ = 88.6% $R^{2(}$(adjusted) = 88.5%

s = 0.4976 with 77 – 2 = 75 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 144.623 | 1 | 145 | 584 |
| Residual | 18.5667 | 75 | 0.2475 | |

| Variable | Coefficient | s.e. of Coef. | t-ratio |
|---|---|---|---|
| Constant | –1.00358 | 0.1541 | –6.51 |
| all occs. | 0.627106 | 0.0259 | 24.2 |

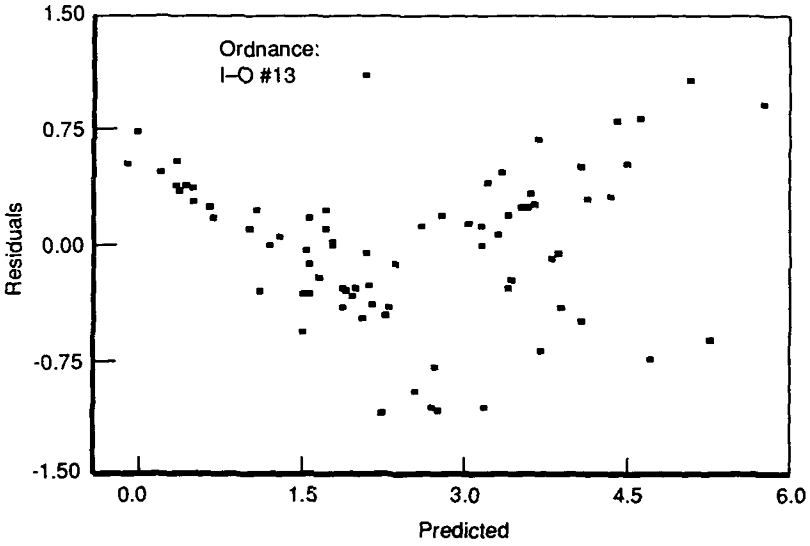

**Fig. 2.7—Scatterplot of Residuals**

plot for the second-order regression indicates no obvious patterns, although some heteroscedasticity appears to be present.

The success of the second-order regression provides evidence of a curvilinear relationship between the two metrics. This curvilinear relationship results, since both metrics have low values for the same industries, the all-occupations metric has higher values for the intermediate industries, and both metrics have the same highly affected

## Table 2.5

## Second-Order Regression Results

Dependent variable is: S-C-OCCS

$R^2 = 91.4\%$ $R^2$ (adjusted) = 91.2%

s = 0.4359 with 77 – 3 = 74 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 149.128 | 2 | 74.6 | 392 |
| Residual | 14.0615 | 74 | 0.1900 | |

| Variable | Coefficient | s.e. of Coef. | t-ratio |
|---|---|---|---|
| Constant | 0.218830 | 0.2851 | 0.768 |
| all occs. | 0.120807 | 0.1064 | 1.14 |
| sq_all occs. | 0.044612 | 0.0092 | 4.87 |

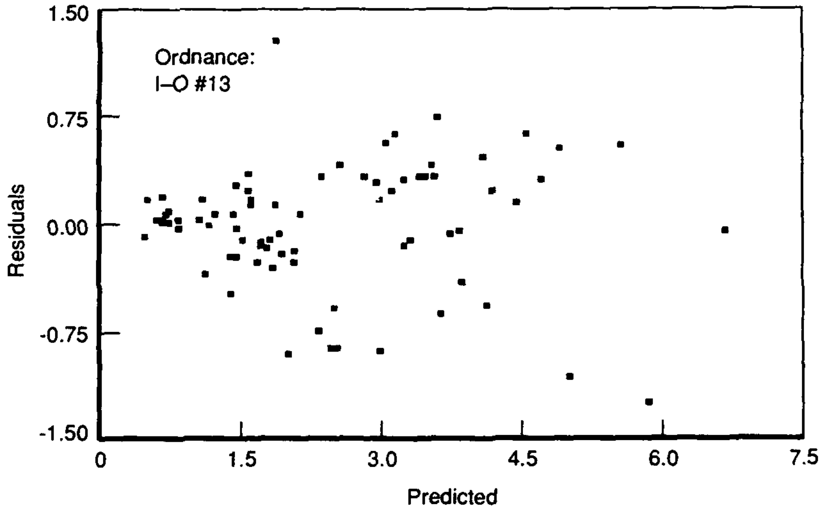

Fig. 2.8—Second-Order Residuals

industries. Since the purpose of the metric is to identify the industries most affected by defense spending, the supply-constrained metric may offer a better way of distinguishing between them and the less-affected industries.

# 3. MEASURING TRADE PERFORMANCE

## GENERAL CONSIDERATIONS

Our aim in this section is to develop a metric that will highlight the differential performance of sectors that are exposed to different degrees of competition for scarce inputs. An ideal metric would screen out the influence of factors that affect the trade performance of all sectors (exchange rate changes, for example) leaving the influence of sector-specific factors. The defense-competing metric developed in the previous section reflects the percentage increase in input costs and output prices that is expected to result from higher wages for skilled workers. Therefore, the trade performance measures should be designed to be sensitive to the changes in trade that would result from a percentage increase in the prices of U.S. products.[1]

A defense-competing industry will face higher costs as a consequence of increased defense spending and would be expected to raise its prices. This should lead to a decrease in the quantity of goods exported, although the amount of the decrease depends on the elasticity of export demand. An increase in costs will also affect imports even though the price of imports is not directly affected. The price of imports relative to domestically produced products has decreased and, therefore, the quantity of imports would be expected to increase. The increase in quantity will depend on the elasticity of demand for imports. Therefore, in industries with a high defense-competing metric, we would expect to observe a decrease in the quantity of exports and an increase in the quantity of imports.[2] Of course, the trade perfor-

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[1] The trade data used for this analysis are official U.S. trade statistics produced by the U.S. Department of Commerce, Bureau of the Census. The publications used were *E.A. 675: U.S. Exports, SIC Division by SIC-based 2-Digit, 3-Digit and 4-Digit Product Codes*, and *I.A. 275: U.S. Imports for Consumption and General Imports, SIC Division by SIC-based 2-Digit, 3-Digit and 4-Digit Product Codes*, for 1980 through 1987. SIC trade statistics were used because they allow easy comparison of imports and exports, and because concordances between the input-output and SIC industry classification systems are available. Comparisons were made at the three-digit SIC level based on nominal dollar values for the calendar years 1980 through 1987.

[2] Data available do not allow direct observation of a change in quantity. Even at the most disaggregated level, trade categories include a changing mix of products, rendering the quantity measures unreliable. For this reason, we have used the trade statistics reported in terms of current dollar value, representing price•quantity (revenue). For an export price increase to lead to a decrease in export revenue, the elasticity must be less than –1. The estimates of demand elasticities for exports indi-

mance of individual industries is affected by a large number of other factors that may have nothing to do with the increase in defense spending. These influences would show up as noise in our measurement of trade performance.

An appropriate trade performance measure would combine the import and export performance into a single number that could be compared with the defense-competing metric. Unfortunately, a number of characteristics of trade flows make this measurement more difficult. In particular, three characteristics of exports and imports during this period have to be considered in the development of the trade metric:

- Industries vary greatly in size, both in a comparison of imports and exports, and in comparison to other industries,
- Imports in virtually all categories grew much more rapidly during the period than exports, and
- Certain industries could be characterized as "growth" industries where both imports and exports grew more rapidly than the all-export and all-import averages, while "mature" industries grew more slowly or declined in terms of both exports and imports.

Each characteristic has implications for the trade metric.

Because the volume of trade varies widely across industries, the absolute growth in surplus or deficit for a particular industry may not be a good measure of trade performance. For example, an increase in the trade deficit for a particular industry could occur despite a much larger growth rate of exports if the volume of imports was substantially larger in the base period. Trade measures based on rates of change rather than absolute growth control for the size of the industry in the base period and also control for the the potential imbalance of imports and exports within an industry.

A second difficulty in measuring U.S. trade performance is that imports as a group performed much better than exports during the period from 1980 through 1987. For example, a comparison of the import and export rates of change from 1980 through 1987 shows that only 6 of 71 three-digit SIC industries had a higher export growth rate than import growth rate. The poor overall performance of exports in comparison with imports has been attributed to the high value of the dollar, high GDP growth rates in the United States in comparison with other countries, and other factors. However, the purpose of this research is to determine whether the poor perfor-

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cate that this assumption is not unrealistic. See App. A for sources of elasticity estimates.

mance of particular industries in international trade was related to defense spending. Since all industries performed relatively poorly, a simple comparison of imports and exports is uninformative.

A more useful measure of industry trade performance would control for the overall rate of import and export growth. The measures developed for this research compare the individual industry's export performance to the all-export average and compare the individual industry's import performance to the all-import average. Operationally, we have included only trade from the 71 SIC 3 categories (manufactures) in our all-import and all-export averages. The prices of nonmanufactures, particularly oil and agricultural products, fluctuated wildly over the period and would distort the measurement. Also, the trade performance of manufactures can be more directly linked to the effect of the defense-competing metric using the current data sources than the performance of nonmanufactures.[3]

Individual export or import performance measures—even if based on the difference between the individual industry and the all-export or all-import average—are not sufficient. In industrial sectors where *trade is expanding rapidly* (computers or electronic components may be examples), both imports and exports increase. Whether or not we judge trade performance in these sectors to be "good" will depend on the growth of imports relative to the growth of exports in that industry.

## SPECIFIC CRITERIA

These general considerations for the trade metric can be incorporated into more formal criteria to evaluate potential trade performance metrics. In particular, we consider three very specific patterns of change in trade flows and note how each should be reflected in a reasonable metric of trade performance. We do not argue that any of these three cases is likely to have occurred. We do suggest, though, that a metric that fails to produce a sensible result in any of these three cases cannot be considered a reasonable metric and should be dismissed from further consideration.

In the remainder of this draft, $X_i$ and $M_i$ will denote the values (in nominal terms) of exports and imports of commodity $i$, respectively. $X$ and $M$ will denote the values of total exports and total imports—the sums, respectively, of all the $x_i^s$ and $M_i^s$. $\Delta$ denotes a change in a

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[3] Additional information on these reasons is presented in App. D.

quantity. $\Delta X_i$, therefore, is the change in the value of exports of commodity $i$.

### Insensitivity to Relative Price Changes

Detailed statistics of U.S. trade are compiled only in nominal terms. In devising a metric, therefore, we must make allowance for the fact that even if nothing real changes, the value of imports or exports may change as a consequence of price changes.

Consider, then, the following case. There is no change in real trade flows. The volumes of all imports and exports remain exactly the same. Suppose that the prices of all commodities, with one exception, rise by $p$ percent. The one exception is commodity $i$. The price of this commodity rises by $p_i$ percent. In this case, there will certainly be changes in the values of imports and exports of commodity $i$; each will have risen by $p_i$ percent. Since nothing real has changed, however, it hardly makes sense to characterize the trade performance of the sector producing commodity $i$ as either good or bad. In this case, the trade performance metric should reflect neutral trade performance.[4]

Note that we do not necessarily want to characterize trade performance as neutral when import and export prices of commodity $i$ change by different amounts, even if there are no changes in real trade flows. If the price of exports of commodity $i$ goes up by more than the price of imports of the same class of commodities and real trade flows do not change, we should consider this as good trade performance. U.S. producers of commodity $i$ have managed to hold onto their foreign markets and stave off import competition in spite of higher relative export prices.

### Insensitivity to Uniform Growth in Imports or Exports

Some factors will affect the performance of all imports or of all exports. More rapid income growth in the United States, for example, will bring increases in imports of most commodities. A rise in the value of the dollar relative to other currencies will typically weaken the performance of all exports and make all imports appear more attractive. Certainly, U.S. trade flows were strongly influenced by such

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[4] This criterion precludes the use of measures that are based on the absolute values (surpluses or deficits) of the exports and imports. For example, if imports of an industry were twice as large in absolute value terms as exports, a price rise of $p$ percent for all products would result in what appeared to be a good performance for imports despite the fact that there was no real change in trade flows.

factors during the early 1980s. Our overall research aim is to test whether the industries competing most directly with defense contractors for scarce inputs showed worse trade performance than did industries that did not face such competition. To do this, we should try to abstract from underlying circumstances that may have affected the trade performance of all industries and that had nothing to do with the defense buildup. Another way of saying this is that we are interested in how increased defense spending may have affected the *relative performance* of U.S. industries in international trade, as opposed to the overall *volume* of imports or exports.

Ideally, we would adjust all trade flows for income and exchange rate effects. To do so, of course, would require estimates of income and price elasticities for all categories of imports and exports. Unfortunately, the necessary elasticity estimates are not available for the detailed trade categories that we are using for our analysis. The next best course may be to assume that these elasticities are equal across all categories of imports and across all categories of exports (although not necessarily the same for imports and for exports). Thus, a change in income or a change in exchange rates will affect the value of all imports equally and the value of all exports equally.[5]

Consider, then, the case where imports of all commodities grow by the same amount. Presumably, this uniform growth is due to some economy-wide phenomenon. No sector-specific factors have influenced trade flows. No one sector has experienced trade performance that is better or worse than any other sector. Consequently, the trade performance metric for any particular sector should show a neutral result.

### Insensitivity to Product Classification

The classification of products into categories for the purposes of reporting trade statistics is necessarily arbitrary. Any trade category could be split into smaller categories. The value of the trade performance metric should not be affected by arbitrary changes in the classification of products.

Consider the following case. Imagine a perfectly homogeneous category of traded products. All products in this category are identical. Now suppose that a statistical clerk decides to divide this category of

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[5] Although this assumption that all elasticities are equal is not realistic, it will not bias our analysis unless the differences are systematically related to the defense-competing metric.

products into two categories—the first including all imported or exported items with even serial numbers and the second made up of all items with odd serial numbers. Presumably serial numbers are irrelevant to import or export demand, and our trade performance metric should show that the trade performance of each of the two new categories is identical to the trade performance of the original combined category.

Another way of saying this is that the trade performance metric is insensitive to the scale of imports or exports. The value of the metric should not be influenced by the magnitude of trade flows. If the value of imports and exports in a category is changed by the simple redefinition of the category, the value of the metric should not change.

Formally, if the values of the trade performance metric for categories $i$ and $j$ are equal, then the value of the metric for the category combining $i$ and $j$ must be equal to the value of either of the original categories independently.

## TRADE PERFORMANCE MEASURES

The requirements for a reasonable trade performance metric described in the preceding subsection may not appear to be particularly stringent. Perhaps surprisingly, we have not been able to devise a single metric that meets all three of these requirements exactly.[6] We have succeeded, though, in identifying three different trade performance metrics that meet the requirements (at least approximately) under certain plausible conditions. In this subsection, we describe these three metrics and discuss the circumstances in which they satisfy the conditions outlined above. As above, $X_i$ and $M_i$ denote the values (in nominal terms) of exports and imports of commodity $i$, respectively. $X$ and $M$ denote the values of total exports and total imports—the sums, respectively, of all the $X_i$s and $M_i$s. $\Delta$ denotes a change in a quantity. $\Delta X_i$, therefore, is the change in the value of exports of commodity $i$. In all three metrics, a positive value of the metric indicates a "good" trade performance, and a negative value indicates a "poor" trade performance.

The first metric we propose for the trade performance of sector $i$, $F_i$, is calculated by the following formula:

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[6] See App. C for a more detailed discussion of the performance of the metrics with regard to these criteria.

$$F_i = \frac{\dfrac{\Delta X_i}{X_i}}{\dfrac{X - \Delta X_i}{X - X_i}} - \frac{\dfrac{\Delta M_i}{M_i}}{\dfrac{M - \Delta M_i}{M - M_i}} .$$

In essence, the metric forms the ratio of the percentage change in the value of exports in category i to the percentage change in the value of exports in all other categories and subtracts from this a similar ratio of imports. If exports in category *i* account for an increased share of total exports—that is, if the value of exports in category *i* rises by a larger percentage than the value of all other exports—while imports in category *i* simply maintain their share of total imports, the first term in the formula will be greater than one and the second term will equal one. The result will be a positive value of the metric, a reflection of "good" trade performance. The reverse will be the case if imports in that category take a larger share of total imports while the share of category *i* in exports remains the same. "Neutral" trade performance is reflected in a value of zero.

The second metric, $G_i$, is similar but not identical to the first. It is calculated as:

$$G_i = \frac{\dfrac{\Delta X_i}{X_i}}{\dfrac{X - \Delta X_i}{X - X_i}} - \frac{\dfrac{\Delta M_i}{M_i}}{\dfrac{M - \Delta M_i}{M - M_i}} .$$

This metric is identical to the first metric, except that the denominators include industry *i*. Therefore, metrics *F* and *G* show similar results when industry *i* accounts for a small share of total imports and total exports.[7]

The third metric based on the relative ranks of export and import trade performance is calculated as:

$$H_i = \text{rank}\frac{\Delta X_i}{X_i} - \text{rank}\ \frac{\Delta M_i}{M_i} .$$

A rank of 1 indicates the slowest growing and *n* the fastest growing export or import industry. For example, the computer industry ranked 70 out of 71 industries (the second fastest growing) in terms of exports, and ranked 71 out of 71 (the fastest growing), in terms of imports, so $H_{computers} = 70 - 71 = -1$. This metric indicates that im-

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[7] See App. C for further details.

ports of computers performed slightly better than exports over this period.

The meaning of the rank metric can be displayed graphically, since the greater the positive or negative slope of the line, the better or worse the trade performance (Fig. 3.1).

The computer industry was at or near the top of both the import and export rankings and, therefore, the metric for the computer industry is near zero. In contrast, the steep downward slope of the line connecting the import rank with the export rank of iron and steel indicates that imports performed significantly better than exports in that industry. The metric of –63 reflects the differential performance of imports and exports. Similarly, exports of motorcycles performed significantly better than imports, and the metric reflects that performance.[8]

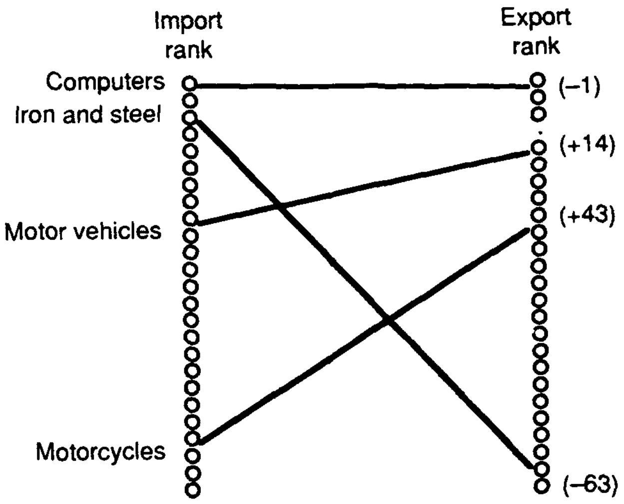

Fig. 3.1—Metric *H* Illustration

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[8] For a discussion of the circumstances in which these metrics meet the minimal requirements for a trade performance metric discussed above, see App. C.

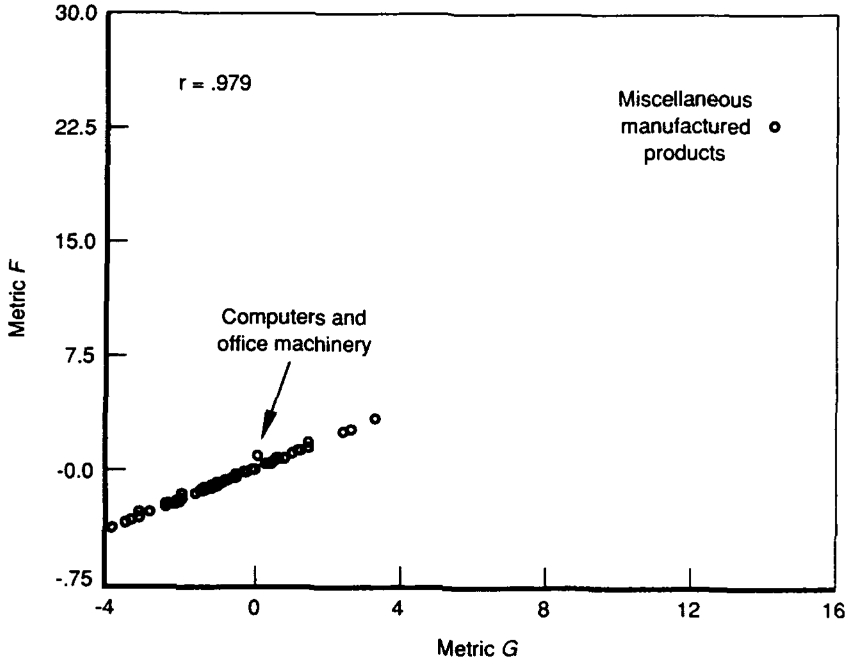

**Fig. 3.2—Scatterplot of Trade Metrics *F* and *G***

## COMPARISON OF METRICS

It is useful to compare the values of the three metrics using data for 71 SIC categories for a variety of years. Figure 3.2 is a scatterplot of trade metrics *F* and *G* based on changes in trade from 1980 through 1987.

The scatterplot shows that for most industries, the two metrics produce nearly equal values. There are two cases, though, in which the two metrics yield substantially different values.[9] Industry values for metrics *F* and *G* are similar when the trade share of the individual industry is relatively small or when the industry growth is similar to the all-export or all-import average. In two cases, however, neither of these criteria is met. These are SIC categories 357, "computers and office machinery," and 399, "miscellaneous manufactured products." (The points lie directly above the 0 and 14 on the horizontal axis, re-

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[9] *See App. C for further information of the differences between metrics F and G.*

spectively.) For computers, the different values arise both because computers accounted for a large share of U.S. exports in 1980 (more than 7 percent) and because the growth of trade in this category has been very different from the growth of all trade. The value of exports of "computers and office machinery" rose 116 percent from 1980 to 1987, compared with only a 29 percent increase for all manufactured exports. The value of imports in this category rose 610 percent compared with 155 percent for all manufactured imports. For "miscellaneous manufactured products," the problem is almost entirely on the export side.[10] Although these miscellaneous products did not account for a particularly large share of total exports in 1980 (about 2.5 percent), they did grow very rapidly compared with all manufactured exports (431 percent compared with 29 percent). Both the import share of these products and the growth of imports were unremarkable.

Figure 3.3 shows the scatterplots of metric *F* compared with metric *H* and metric *G* compared with metric *H*. These plots indicate that there is a substantial amount of variation between either metrics F or *G* and metric *H*. The differences between metrics *F* and *G* and metric *H* are based on the cardinal and ordinal scale comparisons. Metric *H* is based on a ranking of the specific industry's export or import trade performance in comparison with other export industries, whereas metrics *F* and *G* are based on a ratio. As a result, metric *H* is less sensitive to differences in the overall growth rates of imports and exports.

For example, the outlier in the upper right-hand corner in both plots is miscellaneous manufactured products. Metrics *F* and *G* have high values (7.2 and 6.5 standard deviations above the mean, respectively) for this industry, whereas the rank-order metric is relatively insensi-

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[10] Three factors may be responsible for the growth in this category. Export documentation for certain U.S. shipments to Canada are often poorly prepared, and the products that cannot be classified are placed in this category. In addition, the concordance between the export categories and the SIC categories may not be complete for certain types of products, which may also result in products that belong in other categories being assigned to this SIC. Finally, new products may not be easily placed in an existing trade category. These may also be areas of rapid growth. Depending on the type of exports that are included in this category, this introduces a potential source of bias in the trade performance measure. If the exports in SIC 399 are primarily from defense-competing industries, this would lower their observed performance in their original categories and potentially lead to a Type I error—incorrectly rejecting the null hypothesis. On the other hand, if the miscellaneous exports were primarily from nondefense-competing industries, this would lower their relative performance, increasing the chance of a Type II error.

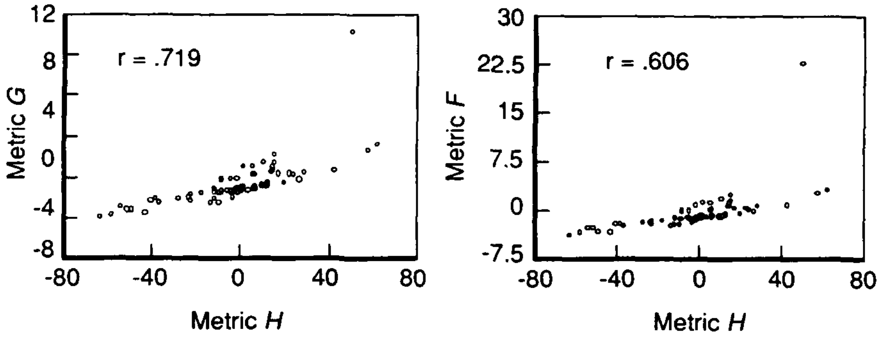


**Fig. 3.3—Scatterplots of Metrics *F* and *G* Compared with *H***

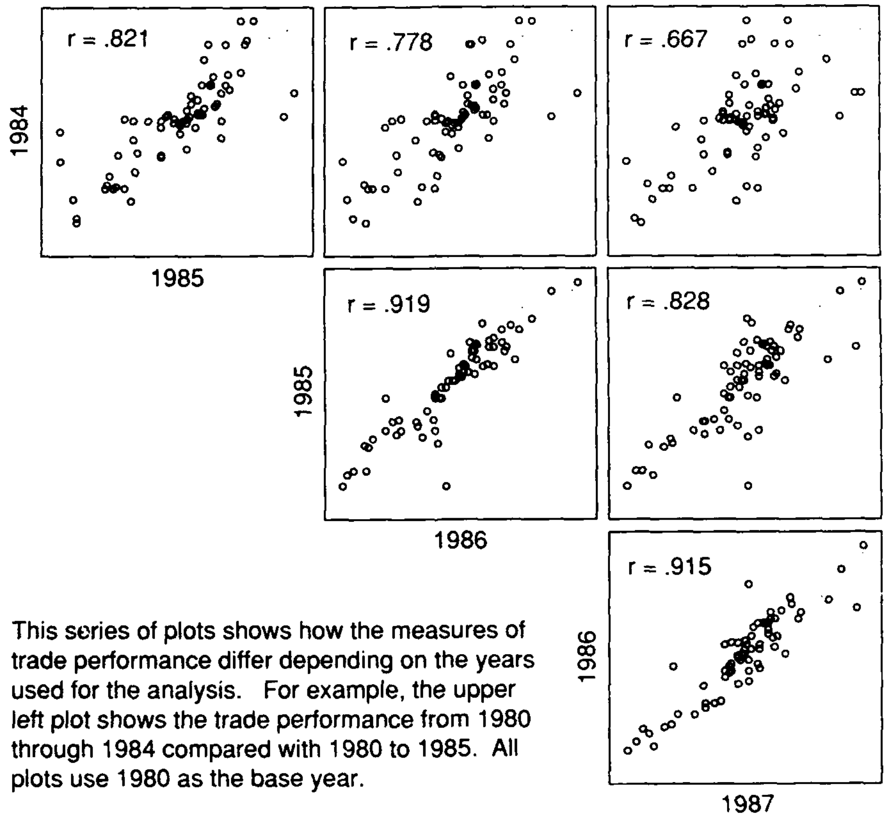
tive to these types of statistical outliers (1.9 standard deviations above the mean).

Another difference between metrics *F* and *G* and metric *H* is in the relative weight they place on import and export performance. Although all three metrics take into account the relative performance of both exports and imports, both metric *F* and metric *G* are largely determined by exports. Because of the more rapid growth of imports during the period, the denominators of the import components of metrics *F* and *G* are substantially larger than the denominators of the export components. As a result, the export fractions are larger than the import fractions and have a greater influence on the overall trade metric. For example, the correlation between *F* and the export component of *F* is .968, and the correlation between *F* and the import component of *F* is –.149. Similarly, the correlation between *G* and the export component of *G* is .944, and the correlation between *G* and the import component of *G* is –.205. Contributions of the export and import components to metric *H* are roughly equal. The correlation between *H* and the export component of *H* is .621, and the correlation between *H* and the import component of *H* is –.598. As a result, the metric *H* is more sensitive to changes in import performance, and when these are substantial, there is a significant difference between the metric *H* and metrics *F* or *G*.

## COMPARISONS BETWEEN YEARS

In addition to comparisons among the three metrics, it is also useful to examine the results of trade performance measures over the years of interest for the analysis. The effects of the increases in defense spending might occur immediately after the defense buildup or with a lag of a few years.[11] Therefore, the effects of defense spending should be compared with the trade performance for a series of years to capture any possible lagged effects. This raises the question of how the trade performance measures differ over periods of possible interest.

Figure 3.4 is a plot matrix of the trade metric $H$ from the pre-defense-buildup year of 1980 through the years 1984, 1985, 1986, and



This series of plots shows how the measures of trade performance differ depending on the years used for the analysis. For example, the upper left plot shows the trade performance from 1980 through 1984 compared with 1980 to 1985. All plots use 1980 as the base year.

Fig. 3.4—Plot Matrix of Metric *H* for Years 1984–1987

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[11] Longer lags are plausible but are unlikely to lead to statistically significant effects.

1987.[12] We defined 1983 as the year most likely to produce cost increases in defense-competing industries and assumed that these cost increases would have an effect on trade flows with a one-year to four-year lag. The correlations are shown in the upper left corner of each plot.

Not surprisingly, the differences between trade performance measures for consecutive years (as shown by the first plot in each row) are relatively small but increase over time. This is especially apparent in the near linear relationships for the plots comparing the values for 1985–1986, and 1986–1987. It is also evident that the differences between the years 1984 and 1985 are greater than the differences between other consecutive years. As a result, tests of association using the trade performance measures from 1980 through 1984 may produce significantly different results than the results for 1980 through 1985, 1986, or 1987.

## TRADE METRIC VALUES

The following tables report values for the three trade performance metrics. Each table shows the 15 manufacturing industries with the "best" trade performance according to the individual metrics and the 15 industries with the "worst" trade performance. The industry with the best performance over this period is SIC 399, "miscellaneous manufactured products," largely because of the artifacts of the data mentioned above. Other industries with good trade performance include SIC 306, "plastic and rubber medical supplies," and SIC 383, "optical instruments." A number of defense-competing industries also appear on the list of best trade performances, including SIC 367, "electronic components" and SIC 369, "electrical machinery."

The list of industries with the "poorest" trade performance is headed by SIC 332, "iron and steel products." A number of defense-competing industries are also among those on this list, including SIC 358, "service industry machines," SIC 373, "yachts," and SIC 344, "fabricated structural metal products."

A comparison of Table 3.1 based on trade metric $F$ and Table 3.2 based on trade metric $G$ shows that there is little difference between the best and worst industry performances using these two metrics.

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[12] Metrics $F$ and $G$ cannot be calculated for changes from the base period 1980 through 1984, 1985, or 1986, since the value of exports showed virtually no change over that period.

This is confirmed by the correlation between the metrics of .979 for the entire list of 71 manufacturing industries.

The rank-order trade metric results (metric *H*, Table 3.3) are substantially different from the previous metrics. These results are less sensitive to the outliers such as the growth in the "miscellaneous manufactured products." In addition, the measure places somewhat greater importance on imports than the previous metrics. As a result, the best trade performances based on metric *H* and SIC 306, "plastic and rubber medical supplies," and 359, "nonelectric machine parts." "Iron and steel products" (SIC 332) remains the industry with the worst trade performance.

## Table 3.1

## Trade Metric *F* Best and Worst Performers

| SIC | Industry |
|---|---|
| | Best Performance |
| 399 | Miscellaneous manufactured products |
| 306 | Plastic or rubber medical supplies |
| 383 | Optical instruments |
| 313 | Leather, cut to shape |
| 367 | Electronic components |
| 319 | Miscellaneous leather goods |
| 369 | Electrical machinery, nspf[a] |
| 384 | Surgical and medical instruments |
| 366 | Communication equipment, nspf |
| 357 | Computers and office machines |
| 375 | Motorcycles and bicycles |
| 385 | Ophthalmic goods |
| 372 | Aircraft and parts[b] |
| | Worst Performance |
| 332 | Iron and steel products |
| 316 | Leather luggage |
| 358 | Refrigerators and service industry machines |
| 393 | Musical instruments |
| 373 | Yachts and pleasure boats |
| 353 | Construction and oil field machinery |
| 324 | Cement |
| 344 | Fabricated structural metal products |
| 328 | Cut stone or stone products |
| 395 | Pens, pencils, and artist's materials |
| 331 | Steel mill products |
| 323 | Glass products |
| 341 | Drums, cans, or boxes of metal |

[a] Not elsewhere specified.

[b] The category of aircraft and parts includes both commercial and military products. A relatively strong performance in military products would suggest that some other mechanism such as economies of scale might be important. Although both U.S. exports and U.S. imports of military aircraft and parts more than doubled during the period, the performance of the military aircraft exports was better relative to the performance of all exports and was a reason for the category being near the top of the list.

## Table 3.2

## Trade Metric *G* Best and Worst Performers

| SIC | Industry |
|---|---|
| | *Best Performance* |
| 399 | Miscellaneous manufactured products |
| 306 | Plastic or rubber medical supplies |
| 383 | Optical instruments |
| 313 | Leather, cut to shape |
| 319 | Miscellaneous leather goods |
| 367 | Electronic components |
| 384 | Surgical and medical instruments |
| 369 | Electrical machinery, nspf |
| 366 | Communication equipment, nspf |
| 375 | Motorcycles and bicycles |
| 385 | Ophthalmic goods |
| 372 | Aircraft and parts |
| 371 | Motor vehicles and parts |
| | Worst Performance |
| 332 | Iron and steel products |
| 316 | Leather luggage |
| 358 | Refrigerators and service industry machines |
| 393 | Musical instruments |
| 353 | Construction and oil field machinery |
| 373 | Yachts and pleasure boats |
| 344 | Fabricated structural metal products |
| 324 | Cement |
| 331 | Steel mill products |
| 395 | Pens, pencils, and artist's materials |
| 328 | Cut stone or stone products |
| 323 | Glass products |
| 341 | Drums, cans, or boxes of metal |

## Table 3.3

## Trade Metric *H* Best and Worst Performers

| SIC | Industry |
|---|---|
| | Best Performance |
| 306 | Plastic or rubber medical supplies |
| 359 | Nonelectrical machine parts |
| 383 | Optical instruments |
| 399 | Miscellaneous manufactured products |
| 375 | Motorcycles and bicycles |
| 376 | Missiles and space vehicles |
| 372 | Aircraft and parts |
| 343 | Heating equipment |
| 326 | Ceramic products or china |
| 346 | Metal forgings and stampings |
| 301 | Tires and tubes |
| 311 | Tanned and finished leathers |
| 313 | Leather, cut to shape |
| | Worst Performance |
| 332 | Iron and steel products |
| 316 | Leather luggage |
| 373 | Yachts and pleasure boats |
| 353 | Construction and oil field machinery |
| 393 | Musical instruments |
| 358 | Refrigerators and service industry machines |
| 395 | Pens, pencils, and artist's materials |
| 341 | Drums, cans, or boxes of metal |
| 324 | Cement |
| 327 | Concrete, gypsum, and plaster products |
| 362 | Electrical industrial apparatus |
| 321 | Flat glass |
| 328 | Cut stone or stone products |

# 4. TESTS OF ASSOCIATION

This section describes the tests of the relationship between the trade performance metrics and the defense-competing metrics for 71 three-digit SIC industries. The question is whether the sharp increase in defense spending had a negative impact on the trade performance of defense-competing industries. A finding confirming such an effect would be a negative relationship between the trade performance and defense-competing measures. The second part of this section discusses the methods used in this analysis and the ways in which these methods might produce results that are different from the actual effects of defense spending on the economy.

## THE ASSOCIATION BETWEEN DEFENSE SPENDING AND TRADE PERFORMANCE

Seventy-two different combinations of trade and defense-competing metrics were tested to determine whether there is any relationship between defense spending and trade performance. Different trade metrics and different yearly combinations are incorporated into the analysis to test the sensitivity of the results to different trade metrics and to different lags in the effect of defense spending.[1] In addition, there are a number of versions of the defense-competing metric, based on different assumptions about the elasticity of final demand for products and assumptions about the elasticity of supply for labor.[2]

Figure 4.1 displays the scatterplot and the regression line for one combination of trade performance and defense-competing measures. The results are typical in that the scatterplot and the statistical analysis show no evidence of a negative relationship between the two measures. The slope of the regression line is .067, with a t-statistic of .21, indicating that there is no statistical evidence for either a positive or negative relationship between the two measures.[3] In addition,

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[1] Six different trade metrics were tested: metrics $F$ and $G$ for changes from 1980 through 1987, and metric $H$ for changes from 1980 through 1984, 1985, 1986, and 1987.

[2] Each trade performance metric is compared with 12 defense-competing metrics.

[3] The regression cannot be used in the form $\Delta P / P = \beta(\Delta Q / Q)$, since reliable quantity trade statistics are not available. Using the revenue data available, we estimate that

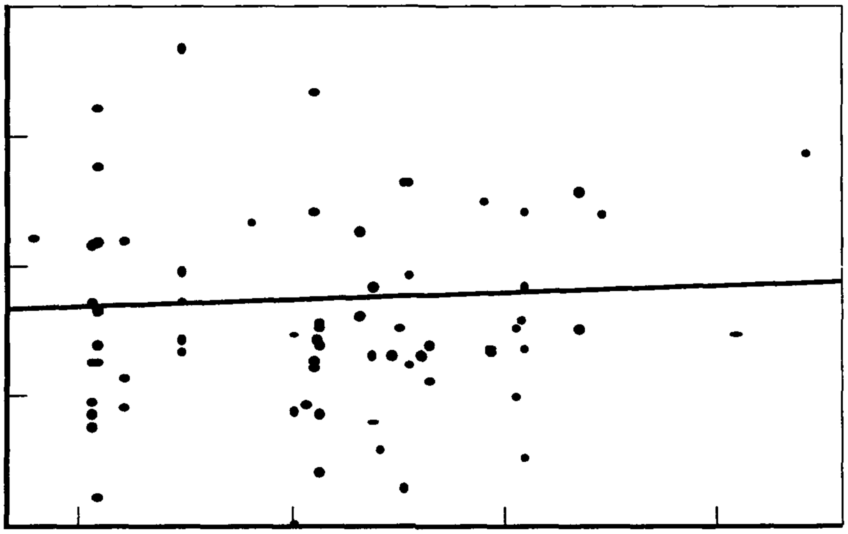

Fig. 4.1—Scatterplot of Trade and Defense-Competing Measures

the point cloud does not appear to have any nonlinear relationships that might be further explored.[4]

## Results Using Different Metrics

Other combinations of trade performance and defense-competing metrics show similar results. The regression results are provided in the following tables, where 12 regression results for each trade performance metric are included in each table. Tables 4.1, 4.2, and 4.3 summarize the results for the three trade metrics $F$, $G$, and $H$, re-

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$$\Delta P / P = \gamma\left(\Delta PQ / PQ = \gamma(P\Delta Q + Q\Delta P)\right)/PQ = \gamma(\Delta Q / Q + \Delta P / P)$$

$$(1 - \gamma)(\Delta P / P) = \gamma(\Delta Q / Q),$$

and

$$(\Delta P / P) = \left(\gamma / (1 - \gamma)\right)(\Delta Q / Q) .$$

[4] This particular combination of defense-competing and trade metrics is the defense-competing metric based on skilled occupations, Mansur personal consumption elasticities, and mixed 0 and 1 government purchase elasticities and the trade metric based on the $F_i$ trade metric from 1980 through 1987.

### Table 4.1

### Metric *F* Regression Results, 1980–1987

| Elasticity Combination | All Occupations | | Skilled Occupations | |
|---|---|---|---|---|
| mpc/g.0 | $R^2$ (%) | 0 | $R^2$ (%) | 0 |
| | Coef. | –0.042 | Coef. | 0.06 |
| | t-stat | 0.18 | t-stat | 0.19 |
| ppc/g.0 | $R^2$ (%) | 0.1 | $R^2$ (%) | 0 |
| | Coef. | –0.05 | Coef. | 0.03 |
| | t-stat | 0.3 | t-stat | 0.09 |
| mpc/g.1 | $R^2$ (%) | 0 | $R^2$ (%) | 0 |
| | Coef. | 0.0006 | Coef. | 0.07 |
| | t-stat | 0.002 | t-stat | 0.16 |
| ppc/g.1 | $R^2$ (%) | 0 | $R^2$ (%) | 0 |
| | Coef. | –0.03 | Coef. | 0.04 |
| | t-stat | 0.118 | t-stat | 0.1 |
| mpc/g.m | $R^2$ (%) | 0 | $R^2$ (%) | 0 |
| | Coef. | 0.003 | Coef. | 0.07 |
| | t-stat | 0.01 | t-stat | 0.21 |
| ppc/g.m | $R^2$ (%) | 0 | $R^2$ (%) | 0 |
| | Coef. | –0.03 | Coef. | 0.04 |
| | t-stat | 0.126 | t-stat | 0.13 |

NOTE: This table displays the results for the regressions with the trade performance metric *F* from 1980 to 1987 as the dependent variable and 12 different versions of the defense-competing metric as the independent variable. The first two columns of results reflect the defense-competing metric assuming all occupations are supply-constrained and using six combinations of final demand elasticity figures as listed on the left-hand side. The last two columns show the same results using only a subset of occupations that are assumed to be supply-constrained.

spectively, based on the trade performance of industries from 1980 to 1987. The first two columns of data present the results for calculations based on the assumption that all occupations have inelastic supply over the period, and the third and fourth columns of data present the results for calculations where only a subset of supply-constrained occupations are used. Each row indicated in the left-hand column refers to a particular set of final demand elasticities. There are six combinations of final demand elasticities based on two per-

## Table 4.2

## Metric *G* Regression Results, 1980–1987

| Elasticity Combination | All Occupations | | Sklled Occupations | |
|---|---|---|---|---|
| mpc/g.0 | $R^2$ (%) | 0.1 | $R^2$ (%) | 0 |
| | Coef. | –0.05 | Coef. | 0.03 |
| | t-stat | 0.31 | t-stat | 0.14 |
| ppc/g.0 | $R^2$ (%) | 0.2 | $R^2$ (%) | 0 |
| | Coef. | –0.06 | Coef. | 0.006 |
| | t-stat | 0.44 | t-stat | 0.03 |
| mpc/g.1 | $R^2$ (%) | 0 | $R^2$ (%) | 0 |
| | Coef. | –0.03 | Coef. | 0.03 |
| | t-stat | 0.14 | t-stat | 0.09 |
| ppc/g.1 | $R^2$ (%) | 0.1 | $R^2$ (%) | 0 |
| | Coef. | –0.06 | Coef. | 0.001 |
| | t-stat | 0.29 | t-stat | 0.005 |
| mpc/g.m | $R^2$ (%) | 0 | $R^2$ (%) | 0 |
| | Coef. | –0.016 | Coef. | 0.04 |
| | t-stat | 0.089 | t-stat | 0.17 |
| ppc/g.m | $R^2$ (%) | 1 | $R^2$ (%) | 0 |
| | Coef. | –0.04 | Coef. | 0.01 |
| | t-stat | 0.25 | t-stat | 0.07 |

NOTE: This table displays the results for the regressions with the trade performance metric *G* from 1980 to 1987 as the dependent variable and 12 different versions of the defense-competing metric as the independent variable. The first two columns of results reflect the defense-competing metric assuming all occupations are supply-constrained and using six combinations of final demand elasticity figures as listed on the left-hand side. The last two columns show the same results using only a subset of occupations that are assumed to be supply-constrained.

sonal consumption elasticities (mpc and ppc) and three government purchase elasticities (g.0, g.1, and g.m).[5]

The first observation is that there are no statistically significant results. The coefficients for the regression are both positive and nega-

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[5] See App. A for a description of these sources.

## Table 4.3

## Metric *H* Regression Results, 1980–1987

| Elasticity Combination | All Occupations | | Skilled Occupations | |
|---|---|---|---|---|
| mpc/g.0 | $R^2$ (%) | 0 | $R^2$ (%) | 1 |
| | Coef. | –0.25 | Coef. | 2.05 |
| | t-stat | –0.14 | t-stat | 0.85 |
| ppc/g.0 | $R^2$ (%) | 0 | $R^2$ (%) | 0.9 |
| | Coef. | –0.3 | Coef. | 1.8 |
| | t-stat | –0.2 | t-stat | 0.81 |
| mpc/g.1 | $R^2$ (%) | 0 | $R^2$ (%) | 0.9 |
| | Coef. | 0.003 | Coef. | 2.6 |
| | t-stat | 0.001 | t-stat | 0.81 |
| ppc/g.1 | $R^2$ (%) | 0 | $R^2$ (%) | 0.9 |
| | Coef. | –0.2 | Coef. | 2.4 |
| | t-stat | –0.08 | t-stat | 0.8 |
| mpc/g.m | $R^2$ (%) | 0 | $R^2$ (%) | 1.2 |
| | Coef. | 0.4 | Coef. | 2.3 |
| | *t-stat* | 0.2 | *t-stat* | 0.93 |
| ppc/g.m | $R^2$ (%) | 0 | $R^2$ (%) | 1.1 |
| | Coef. | 0.18 | Coef. | 2.1 |
| | t-stat | 0.1 | t-stat | 0.89 |

NOTE: This table displays the results for the regressions with the trade performance metric *H* from 1980 to 1987 as the dependent variable and 12 different versions of the defense-competing metric as the independent variable. The first two columns of results reflect the defense-competing metric assuming all occupations are supply-constrained and using six combinations of final demand elasticity figures as listed on the left-hand side. The last two columns show the same results using only a subset of occupations that are assumed to be supply-constrained.

tive, and most of the t-statistics are small.[6] Differences between the regression results using the trade metrics *F*, *G*, and *H* are small, and within the tables for each trade metric, the elasticity combinations listed along the left also have little effect on the regression results. One assumption that does produce systematic changes in the results is the assumption about the elasticity of labor. In the regressions where all occupations are assumed to have a zero elasticity (first two

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[6] In fact, it is somewhat surprising that none of the results are significant, since so many different (although not independent) combinations of measures were attempted.

data columns), the coefficients of the regression are typically negative, although insignificant. When the regressions are calculated with only the occupations assumed to be supply-constrained (third and fourth data columns), the coefficients are typically positive, although still insignificant.

## Results Using Different Years

In addition to the tests of association using different trade performance metrics, it is also necessary to examine the results using trade performance measures over a period of years. Tables 4.4, 4.5, and 4.6

**Table 4.4**

**Metric *H* Regression Results, 1980–1984**

| Elasticity Combination | All Occupations | | Skilled Occupations | |
|---|---|---|---|---|
| mpc/g.0 | $R^2$ (%) | 0 | $R^2$ (%) | 0.3 |
| | Coef. | –0.27 | Coef. | 1.2 |
| | t-stat | –0.15 | t-stat | 0.5 |
| ppc/g.0 | $R^2$ (%) | 0 | $R^2$ (%) | 0.5 |
| | Coef. | 0.04 | Coef. | 1.4 |
| | t-stat | 0.02 | t-stat | 0.63 |
| mpc/g.1 | $R^2$ (%) | 0.3 | $R^2$ (%) | 0.1 |
| | Coef. | –1.17 | Coef. | 1.05 |
| | t-stat | –0.47 | t-stat | 0.33 |
| ppc/g.1 | $R^2$ (%) | 0.2 | $R^2$ (%) | 0.2 |
| | Coef. | –0.88 | Coef. | 1.18 |
| | t-stat | –0.38 | t-stat | 0.39 |
| mpc/g.m | $R^2$ (%) | 0 | $R^2$ (%) | 0.3 |
| | Coef. | –0.25 | Coef. | 1.31 |
| | t-stat | –0.13 | t-stat | 0.52 |
| ppc/g.m | $R^2$ (%) | 0 | $R^2$ (%) | 0.5 |
| | Coef. | –0.49 | Coef. | 1.43 |
| | t-stat | –0.03 | t-stat | 0.60 |

NOTE: This table displays the results for the regressions with the trade performance metric *H* from 1980 to 1984 as the dependent variable and 12 different versions of the defense-competing metric as the independent variable. The first two columns of results reflect the defense-competing metric assuming all occupations are supply-constrained and using six combinations of final demand elasticity figures as listed on the left-hand side. The last two columns show the same results using only a subset of occupations that are assumed to be supply-constrained.

### Table 4.5

### Metric *H* Regression Results, 1980–1985

| Elasticity Combination | All Occupations | | Skilled Occupations | |
|---|---|---|---|---|
| mpc/g.0 | $R^2$ (%) | 0 | $R^2$ (%) | 1.7 |
| | Coef. | –0.02 | Coef. | 2.8 |
| | t-stat | –0.00 | t-stat | 1.1 |
| ppc/g.0 | $R^2$ (%) | 0 | $R^2$ (%) | 1.8 |
| | Coef. | 0.05 | Coef. | 2.6 |
| | t-stat | 0.03 | t-stat | 1.12 |
| mpc/g.1 | $R^2$ (%) | 0 | $R^2$ (%) | 1.4 |
| | Coef. | –0.07 | Coef. | 3.5 |
| | t-stat | –0.02 | t-stat | 1.01 |
| ppc/g.1 | $R^2$ (%) | 0 | $R^2$ (%) | 1.5 |
| | Coef. | –0.07 | Coef. | 3.42 |
| | t-stat | –0.03 | t-stat | 1.03 |
| mpc/g.m | $R^2$ (%) | 0.1 | $R^2$ (%) | 2 |
| | Coef. | 0.61 | Coef. | 3.2 |
| | t-stat | 0.28 | t-stat | 1.18 |
| ppc/g.m | $R^2$ (%) | 0.1 | $R^2$ (%) | 2 |
| | Coef. | 0.52 | Coef. | 3.08 |
| | t-stat | 0.27 | t-stat | 1.2 |

NOTE: This table displays the results for the regressions with the trade performance metric *H* from 1980 to 1985 as the dependent variable and 12 different versions of the defense-competing metric as the independent variable. The first two columns of results reflect the defense-competing metric assuming all occupations are supply-constrained and using six combinations of final demand elasticity figures as listed on the left-hand side. The last two columns show the same results using only a subset of occupations that are assumed to be supply-constrained.

present the regression results for trade performance measure *H* based on the periods beginning in 1980 and ending in 1984, 1985 and 1986. The results are consistent with the results for the period beginning in 1980 and ending in 1987, i.e., there is no statistically significant relationship between the two measures.

## RETRACING THE ANALYSIS

The previous tables provide no evidence that defense spending had a negative effect on the trade performance of the defense-competing

## Table 4.6

## Metric *H* Regression Results, 1980–1986

| Elasticity Combination | All Occupations | | Skilled Occupations | |
|---|---|---|---|---|
| mpc/g.0 | $R^2$ (%) | 0.5 | $R^2$ (%) | 3 |
| | Coef. | 1.15 | Coef. | 3.7 |
| | t-stat | 0.61 | t-stat | 1.4 |
| ppc/g.0 | $R^2$ (%) | 0.5 | $R^2$ (%) | 3.1 |
| | Coef. | 1.03 | Coef. | 3.5 |
| | t-stat | 0.637 | t-stat | 1.5 |
| mpc/g.1 | $R^2$ (%) | 0.5 | $R^2$ (%) | 2.7 |
| | Coef. | 1.71 | Coef. | 4.7 |
| | t-stat | 0.64 | t-stat | 1.4 |
| ppc/g.1 | $R^2$ (%) | 0.5 | $R^2$ (%) | 2.7 |
| | Coef. | 1.48 | Coef. | 4.5 |
| | t-stat | 0.61 | t-stat | 1.4 |
| mpc/g.m | $R^2$ (%) | 1.1 | $R^2$ (%) | 3.2 |
| | Coef. | 1.86 | Coef. | 4.0 |
| | t-stat | 0.89 | t-stat | 1.5 |
| ppc/g.m | $R^2$ (%) | 1 | $R^2$ (%) | 3.2 |
| | Coef. | 1.6 | Coef. | 3.8 |
| | t-stat | 0.85 | t-stat | 1.53 |

NOTE: This table displays the results for the regressions with the trade performance metric *H* from 1980 to 1986 as the dependent variable and 12 different versions of the defense-competing metric as the independent variable. The first two columns of results reflect the defense-competing metric assuming all occupations are supply-constrained and using six combinations of final demand elasticity figures as listed on the left-hand side. The last two columns show the same results using only a subset of occupations that are assumed to be supply-constrained.

industries. This suggests that whatever effects defense spending may have had were too small to observe among all the other changes that affected the trade performance of industries during the mid-1980s. It is also possible, however, that certain data or assumptions may have led to this finding. As a result, it is useful to examine more closely the methods used to test this theory of how defense spending might affect trade. This would allow us to indicate the ways in which noise or bias might have affected the analysis. This examination may also suggest other influences that we did not consider that could lead to these results.

Figures 4.2 through 4.5 illustrate the steps involved in the development of the hypothesis. Each shaded rectangle indicates a type of data or intermediate result. Each flat rectangle indicates a step in the data transformation. Figure 4.2 begins with the actual increase in defense spending. The final result in Fig. 4.5 is "poor performance in international trade," a result that was not demonstrated by our research. Therefore, some step in the chain of events that we have hypothesized did not happen, or the effect was too small to measure. A summary of the assumptions underlying each step provides some potential reasons as to why we did not observe any effect of defense spending.

### Steps 1 and 2

The analysis begins with the actual data on defense spending from the budget. Two transformations convert this original round of spending increases into direct demand for industries and into increases in total demand by industry (see Fig. 4.2). These calculations

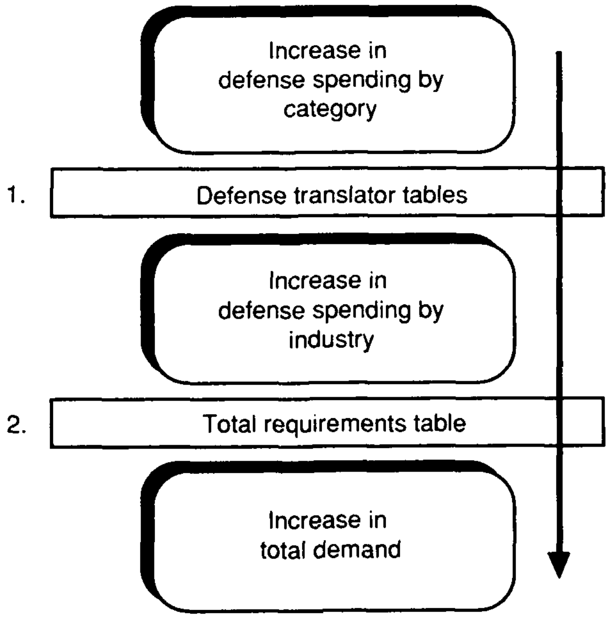

Fig. 4.2—Increases in Demand

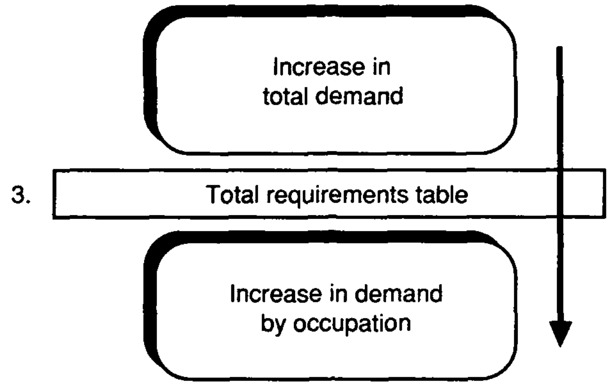

**Fig. 4.3—Increase in Demand by Occupation**

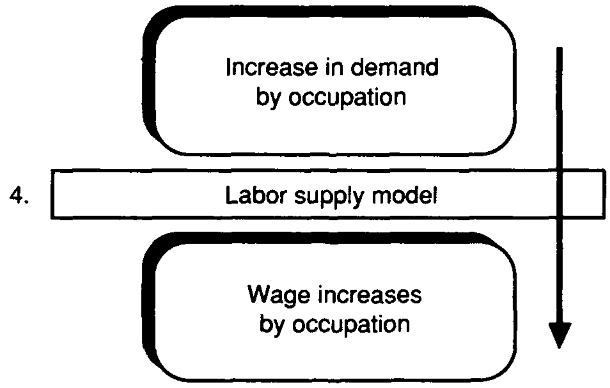

**Fig. 4.4—Labor Supply Model**

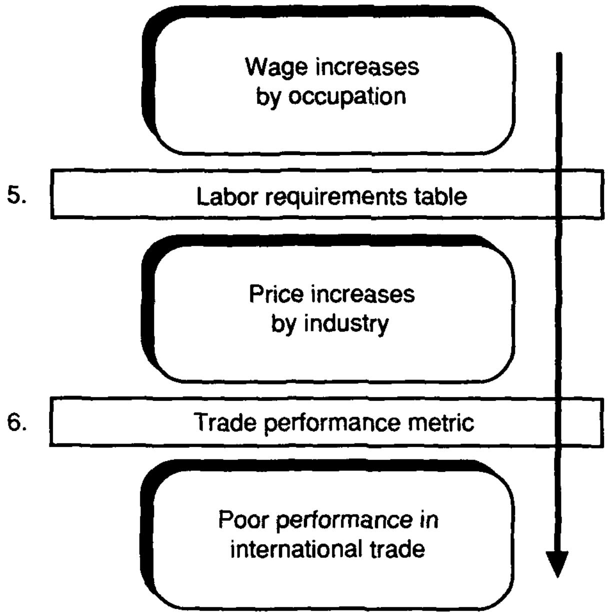

Fig. 4.5—Final Steps of the Model

depend upon the accuracy of the coefficients in the defense translator tables and in the total requirements tables. There is no reason to believe that these tables are not accurate representations of the production process as it existed in the early 1980s.

However, our calculations using the input-output tables are likely to underestimate the flexibility of the economy to changes such as the increase in defense spending. Input-output tables such as the total requirements table are based on a highly simplified characterization of the production process. The "recipe" for the production of every product is assumed to be rigidly fixed: To make one unit of A, we need so many units of B, so many units of C, so many units of labor of type D, and so on. These production "coefficients" are recorded in the input-output tables estimated by the Department of Commerce. We know that it would be possible to make this output in other ways in different circumstances. But since these other circumstances do not exist and generally have not existed, we cannot actually observe these other mixes of inputs. We are forced then to assume that changes in outputs will require proportional changes in the inputs we observe industries to be using today.

One way in which this assumption could lead to an overestimate of inputs is the existence of economies of scale. For a variety of reasons, it may be possible to increase the production of certain products, say automobiles, from 50 to 100 without doubling the inputs of steel, machinery, electricity, etc. Input-output tables imply that all industries exhibit constant returns to scale.

As a result of this simplification, the intermediate inputs required to supply the defense buildup may have been overestimated. However, this overestimate will not necessarily bias the results. The bias would occur only if the overestimate varies systematically with the order of the industries in the defense-competing metric. For example, if economies of scale are especially important in the industries that have high levels of the defense-competing metric, this would result in an upward bias in our estimates of the metric for those industries. The increases in costs resulting from higher wages might be offset by the scale economies provided by increased demand.[7]

We further assume, though—almost certainly contrary to reality—that demand for any product is insensitive to the price for other products. In the case of complimentary goods, so-called cross-price elasticities are actually negative: An increase in the cost of gasoline will decrease demand for automobiles. When goods are substitutes, cross-price elasticities will be positive: An increase in the costs of automobile ownership will increase usage of public transit. Although we know that many cross-price elasticities are not zero, we have little choice but to ignore them. It is already a tall order to develop estimates of own-price elasticities for a detailed disaggregation of total output. If we had to develop estimates of cross-price elasticities also, the data requirements for the model would grow as the square of the number of sectors, and rapidly growing data needs would quickly render any detailed analysis intractable. The consequence of ignoring cross-price elasticities will probably be that our estimates of the consequences of changes in defense spending will be overly concentrated in a few sectors.

As a result of this simplification, we may have incorporated an upward bias in the prices of certain intermediate products. This could occur because substitution is most likely to occur from intermediate inputs that have increased substantially in price. Both the defense producers and the defense-competing industries are likely to use sub-

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[7] Anecdotal evidence suggests that economies of scale (or large minimum efficient scale) may be important in high-technology industries such as aircraft or electronics production.

stitutes for intermediate inputs with the largest increases in prices. Therefore, these intermediate inputs are likely to rise more slowly in price than is indicated by our model, and the substitutes are likely to have somewhat larger increases in prices. This would lead to an upward bias in the estimated costs of defense-competing industries and a downward bias in the industries that use substitutes for these products. Therefore, the actual price increases that result from defense spending are likely to be less concentrated in the defense-competing industries than our calculations suggest.

Our models also fail to take into account the fact that changes in defense spending will change the real income of nondefense consumers and that these changes in income will affect consumer demand, to varying degrees, for all goods. We ignore these income effects for reasons of analytic tractability. Generally, changes in income resulting from changes in defense spending will not be large. The categories of defense spending that are the subject of our analyses, procurement and RDT&E, increased from 1.54 percent of GNP in 1980 to 2.18 percent of GNP in 1983.[8] Therefore, the increases are on the order of 1/2 percent of GNP. Ignoring the income effects associated with changes of this magnitude will probably not introduce important errors. This is especially true since the incremental purchases by consumers are unlikely to occur in a concentrated set of industries.

### Step 3

The second stage of the analysis is to estimate the increase in demand by occupation (see Fig. 4.3). The problems that could be introduced in this step are similar to those mentioned above. Inaccuracies in the labor requirements table are possible, but more important, the labor requirements table assumes the same type of fixed coefficients as the input-output tables. In practice, economies of scale in the use of labor are possible. No more design engineers, for example, are likely to be needed to increase production runs of, say, computers or aircraft. Neither must management staffs, accounting departments, and other "overhead" functions expand proportionally with production. In this most recent buildup, for example, a large share of the procurement funds was used to purchase aircraft, missiles, and other systems that had been designed and were already in production. Increases in funding for production would necessarily increase the demand for production-related positions. However, increased production is unlikely to

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[8] *Historical Tables of the U.S. Budget, 1990,* and *Economic Report of the President, 1990.*

have much effect on the design staffs or the overhead positions. Therefore, it is possible that we have overestimated the demand for workers in these occupations.

Substitution is also likely among labor inputs, especially as a result of significant wage increases. If certain kinds of labor are in short supply, firms will figure out how to get by—perhaps less efficiently—with other kinds of labor. This might include loading additional responsibilities on existing trained personnel or rapidly promoting personnel into positions with less than the normal level of training or experience.

As a result, this step is also likely to lead to overestimates of the increases in demand by occupation. The result of these overestimates is that we might expect cost increases greater than what would occur for the entire range of defense-competing industries. These overestimates are not likely to systematically alter the order of our defense-competing metric and therefore should not bias our regression results.

### Step 4

Several important assumptions are introduced in this stage of the analysis by the labor supply model (see Fig. 4.4). One is that the supply of workers within various occupations is fixed over the period of the analysis and that the workers cannot work additional overtime hours.[9] This assumes that the workers with particular skills were fully employed at the beginning of the defense buildup and that workers in specialized occupations were not released from other industries during this period for reasons unrelated to the increase in defense spending. In fact, indicators such as capacity utilization and the unemployment rate indicate that some workers were probably unemployed in 1980 and that many more were probably made available by the downturn in business activity from 1980 to 1983. Capacity utilization in manufacturing dropped by 6 percent from 1980 to 1983 despite the increase in defense spending and the unemployment rate increased by 2-1/2 percent during the same period.[10]

A related assumption implicit in our labor supply model is that the additional workers can be made available only from industry production for public or private consumption. It is possible that total in-

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[9] Data from the Bureau of Labor Statistics, *Employment, Hours, and Earnings*, do not show any sharp increase in the hours worked in the highest defense-competing industries over this period.

[10] *Economic Report of the President*, February 1990, Tables C-51 and C-32.

vestment demand may have been reduced as a result of the increase in defense demand and the resulting higher wages for workers. Investment includes purchases of plant and equipment by business and purchases of housing by individuals. A large percentage of certain industries' production is designated as investment, and in our model, workers could not be drawn from this source. Nearly all of the production of the construction industry, for example, is designated as investment. Other industries that produce a significant amount for investment include the machinery industries, transportation industries, and a number of the high-technology industries. If workers were also squeezed out of production for investment as well as production for consumption, we would have underestimated the availability of skilled workers in the economy. In fact, the level of gross private fixed investment did fluctuate over the period, as shown in Table 4.7.

This study is also based on the assumption that increased defense spending will lead to higher wages. However, it is not necessarily true that sharply increased defense demand will lead to higher wages, even if workers within those occupations are in short supply. Although some authors found that salaries did respond to increases and decreases in defense demand,[11] other research indicates that

**Table 4.7**

**Gross Private Fixed Investment, 1980–1986 (in billions of 1982 dollars)**

| Year | Gross Private Fixed Investment |
|---|---|
| 1980 | 506 |
| 1981 | 547 |
| 1982 | 447 |
| 1983 | 503 |
| 1984 | 664 |
| 1985 | 650 |
| 1986 | 631 |

SOURCE: *Economic Report of the President*, February 1990, Gross Private Fixed Investment, Table C-2; Implicit Price Deflator, Table C-3.

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[11] Freeman (1975), p. 27.

the increased domestic demand may lead to increased backlog or less attention to exports. For example, Gregory suggests that internal demand increases may lead to lower levels of exports even if wages are not greatly affected.[12] These exports might occur as a result of less generous credit terms and a generally less enthusiastic response of suppliers to exports. Artus[13] found that an increase in domestic demand led to an increase in backlog for export orders. These findings suggest that trade performance might be negatively affected even if wages do not increase significantly.

Finally, the labor supply model assumes that entry into certain occupations is strictly limited. This is also unrealistic, since it is likely that promotion and training occur more rapidly when the wages of a certain type of worker increase. The model included only infinitely elastic and completely inelastic occupations—the actual labor supply elasticities are obviously between these two extremes.

These factors suggest that significant numbers of skilled workers may have been available from sources other than production for final demand. As a result, the effect of defense spending on occupations and on industries would be smaller than estimated, but this does not necessarily indicate that the order of the defense-competing industries is inappropriate. The effect of these assumptions implicit in the labor supply model is to overestimate the wage increases that will result from the increase in defense spending and widen the range of the defense-competing metric.

### Steps 5 and 6

The final steps of the model involve some additional assumptions (see Fig. 4.5). The first is that increased costs resulting from higher wages will be converted into increased export prices for each industry. We have no reason to believe that defense-competing industries are price-takers to a greater extent than other industries.

A second assumption is that these increased prices will lead to observable changes in the performance of those industries in international trade. For example, we assume that trade flows will respond to changes in relative prices in terms of a reduction of exports and an increase in imports. The extent of these changes depends upon the elasticities of demand for exports and imports. For example, if the demand for exports is relatively inelastic ($|\varepsilon| < 1$), export revenue

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[12] Gregory (1971), p. 28.

[13] Artus (1973), p. 31.

would actually increase as a result of higher prices. Trade statistics based on quantities rather than revenue would help alleviate this problem, but these are not available. Therefore, we must assume that export and import demand elasticities are relatively elastic ($|\varepsilon| > 1$). Further, we must assume that the elasticities are not correlated with the defense-competing metric.

For example, if the elasticities of demand in international trade for products of "defense-competing" industries were significantly lower than for nondefense-competing products, this could produce the lack of relationship that we observed, even if all the steps up to this point produced correct results. Trade elasticity estimates are not available to the extent necessary to fully test this assumption, but it does not appear that this type of correlation exists.[14]

### Assessing These Shortcomings

One likely effect of these assumptions is to overestimate the effect of defense spending. This would have the effect of "widening" the scale of the defense-competing metric. This can be illustrated by comparing the defense-competing results: those calculated with the assumption that all occupations are characterized by inelastic supply, and those calculated with the assumption that only certain occupations were supply-constrained. The order of the industries is not much different (as illustrated in Fig. 2.6), but the range of the metric may increase as a result of the more restrictive assumptions. This is illustrated in Fig. 4.6, where the plots show that the restrictive assumption (top) not only shifts the metric results to higher levels. It also increases the spread of the results as indicated by the higher standard deviation and larger range.

The assumptions that may lead to this type of result are listed in Table 4.8.

### Influence of Other Factors

One possible cause for the lack of a measurable effect of defense spending on trade performance is that noise in the various data sources swamped any effects of defense spending. One way in which noise might be generated is through the use of a "grain" of analysis that is too large. For example, if defense spending has an effect on

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[14] See App. A for a discussion of the elasticity data.

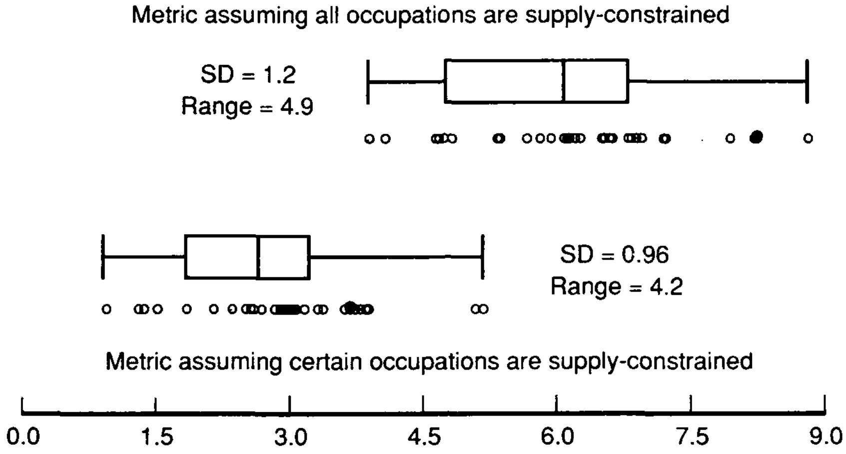

Fig. 4.6—Assumptions Leading to a Wider Range

### Table 4.8

### Assumptions Potentially Leading to Overestimated Results

| Step | Assumption |
|---|---|
| 2 | Constant returns to scale |
| 3 | Constant returns to labor |
| 3 | No substitution among labor types |
| 4 | Fully employed, fixed labor supply |
| 4 | Labor squeezed only from final demand |

some small section of the radio and TV communications industry, then the greater the aggregation of the industry, the less chance we will have to observe that effect. In fact, the size of the "radio and TV communications equipment" industry suggests that the grainsize we have used may be too large. Communications equipment, which is similar to that used by the defense industry, is only a small part of the industry. Radios and televisions are also included, as are records, cassette tapes, and telephone and related products. The shifts in trade that could occur because of changes in tastes or company fortunes in these other sections of the industry could easily swamp the effects of an increase in wages in the communications equipment part of the industry.

Other aspects of the research might also increase the potential for noise to be introduced into the measurement of either the costs or the trade performance of industries. A wide range of factors other than the influence of defense spending are likely to have influenced costs during this period and therefore added noise to the analysis. These factors might include large shifts in input prices such as energy prices, environmental or other regulatory costs, and shifts in labor markets. A range of factors might have introduced noise into our trade performance measures. These might include foreign government support of export industries or restriction of imports, trade shifts as a result of exchange rate shifts or changes in tastes, and variance in the elasticities of demand for imports and exports. If the noise generated by these factors is not systematically related to the measurement, then it will simply require a more sensitive instrument to distinguish between the noise and the signal. However, if the noise is somehow correlated to either the defense-competing or trade performance measures, this might lead to a bias in the analysis. For example, if foreign governments increased subsidies to industries that export defense equipment during this period, this would create a form of bias in our trade measure. Our measure would indicate that imports performed better than exports, even if the U.S. defense buildup did not have a negative impact on the trade performance of industries.

## POTENTIAL POSITIVE EFFECTS OF DEFENSE SPENDING

One potentially interesting source of bias might result if defense spending has positive effects on industry trade performance. One way in which this might occur is through economies of scale. The regression results described above indicate that no significant beneficial effects of defense spending accrue to the defense-competing industries. These regressions show that trade performance is neither positively or negatively related to the defense-competing metric. However, this is not surprising, since the defense-competing industries were selected using specific criteria based on higher costs that they would accrue because of competition for labor inputs.[15]

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[15] If a strong performance in defense exports made up a significant proportion of exports of certain industries, this could lead to the observed results. However, defense exports are highly concentrated in a few SIC groups such as missiles (SIC 372) and aerospace (SIC 376). Eliminating these observations does not significantly affect the results.

A more direct test of the positive contribution of defense spending industries can be designed using the total increase in sales for individual industries that results from defense spending. A measure of the contribution of defense spending to economies of scale in an industry was constructed using the dollar value increase in defense spending from 1980 to 1983 divided by the total output of the industry in 1980. The potential positive contribution of defense spending to industry trade performance was tested by regressing the measures of trade performance on this variable measuring the effect of defense spending. If increases in defense spending lead to improved trade performance, this regression would produce positive coefficients. As indicated in Table 4.9, the regressions for trade performance metrics *F* and *G* produce statistically insignificant results.[16] However, the regressions using metric *H* based on the change in trade performance from 1980 through 1984, 1985, or 1986 show statistically significant results. These mixed results provide some support for the hypothesis that defense spending may have the effect of improving trade performance, possibly through the mechanism of providing economies of scale.[17]

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[16] Descriptions of all of the trade metrics are provided in Sec. 3.

[17] The fact that the different trade metrics provide different results suggests that it may be the particular characteristics of the metric that lead to the statistically significant results. It would not be surprising if the variable measuring the increase in defense spending by industry was highly correlated with either export or import performance, or one that was largely determined by either imports or exports. Therefore, it is surprising that the significant findings are generated with the rank-order metric *H*. As described in Sec. 3, metric *H* is equally correlated with both imports and exports, whereas metrics *F* and *G* are largely determined by exports.

## Table 4.9

## Tests for Positive Effects of Spending

| Trade Performance Measure/Year | Regression Results | |
|---|---|---|
| Metric *F*/1987 | $R^2$ (%) | 0 |
| | Coef. | 0.57 |
| | t-stat | 0.16 |
| Metric *G*/1987 | $R^2$ (%) | 0 |
| | Coef. | –0.29 |
| | t-stat | 0.06 |
| Metric *H*/1987 | $R^2$ (%) | 2.3 |
| | Coef. | 45 |
| | t-stat | 1.27 |
| Metric *H*/1986 | $R^2$ (%) | 5.3 |
| | Coef. | 73 |
| | t-stat | 1.97* |
| Metric *H*/1985 | $R^2$ (%) | 4.3 |
| | Coef. | 66 |
| | t-stat | 1.76* |
| Metric *H*/1984 | $R^2$ (%) | 6.5 |
| | Coef. | 75 |
| | t-stat | 2.2* |

NOTES: This table displays the results for the regressions with the increase in total defense demand as a percentage of industry size as the independent variable, and the various trade performance metrics as the dependent variables. The asterisk indicates that the results are significant at the 0.05 level with 33 degrees of freedom.

# 5. CONCLUSIONS

## IMPLICATIONS

We have been unable to demonstrate any relationship between the degree to which an industry competes with defense production for scarce labor resources and the trade performance of that industry. Consequently, we have been unable to demonstrate any particular link between the rise in U.S. defense spending during the early 1980s and the poor U.S. high-tech trade performance during that same period. To the extent, of course, that increased defense spending contributed to larger federal deficits and in turn to higher dollar interest rates, it probably contributed to the overall disappointing U.S. trade performance during the 1980s. But in this regard, defense spending is no different from any other form of government spending or from private consumer spending.

Our aim in this research has been to test whether increased defense procurement might have had some additional effect on the trade performance of particular U.S. industries beyond what we would expect from any government spending. We examined defense procurement because it generates increased demands for resources in scarce supply. We found no such effect.

The most important implication of this negative finding is that there appears to be no basis for hoping that current and future reductions in defense spending will lead to an improvement in the trade performance of high-technology U.S. industries. Increased defense spending does not appear to have been an important contributor to the decline in the trade performance of these industries. There seems no reason to expect that declining defense spending will contribute to improved performance. Policymakers concerned about U.S. high-tech industries and their competitiveness in international markets should look elsewhere for the causes of current difficulties and sources of future hope.

This research may also have implications for the current debate regarding the future defense strategy. One option being considered is to continue research and development and postpone the large-scale production of the resulting systems until needed. The buildup of the early 1980s was a type of "dry run" for such a strategy, involving a surge in production of systems that had been largely designed in prior years. Since the buildup had no measurable effect on the trade performance of U.S. industries, it suggests that production surges are unlikely to have negative impacts on the trade performance of high-technology industries unless the conditions are substantially different from those of the early 1980s.

## INTERMEDIATE RESULTS

Some intermediate results produced by this research may be of policy interest. For example, this research confirms that the industries most likely to be affected by defense spending are among those that we typically consider high-technology industries. The industries listed as high-technology by the Department of Commerce based on the amount of embodied research and development are similar to the industries at the top of our "defense-competing" list.[1]

A listing of the occupations that are likely to have the largest percentage wage increases as a result of the defense buildup is also an intermediate finding of interest. The ranking of occupations takes into account the additional demand resulting from defense spending and the availability of those workers in private industry. Therefore, larger wage increases would be expected either when there are few of that type of worker in private industry or when higher wages for those workers are unlikely to decrease demand for industry output.

Finally, the trade performance measures provide an indicator of the best and worst performers in international trade. The trade deficit is an important economic measure for both the economy and for individual industries, but the measures developed in this research are more useful in an assessment of performance across a number of industries.

## ADDITIONAL RESEARCH

A number of interesting follow-on research efforts are suggested by this research. This research has focused on the *effects* of defense spending on trade performance. A closer examination of the individual steps involved in testing this hypothesis will provide additional insight into the *mechanisms* through which defense spending might affect economic performance. Several assumptions of the research can be tested by comparing the intermediate results of the research with available economic data.

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[1] Davis (1982).

One research effort would be to examine closely the effect of defense spending on wages. Certain types of employment-related information are available to address this question. These include employment and hours by industry, wages by industry, and some additional information regarding entry and exit into specialized fields of science and engineering. Although these data sources do not coincide directly with the intermediate results produced in this research, they can provide some indication of the difference between the actual data and the predicted results regarding the employment effects of the increase in defense spending.

A second way to study further the mechanism through which defense spending might affect economic performance is by examining the effects of the wage and price increases on the composition of trade. Trade performance was not significantly affected by the defense buildup for a number of potential reasons. One is that there were no significant increases in wages and prices. Alternatively, however, the increases in wages and prices may not have had an effect on trade performance. Therefore, it would be useful to examine the mechanisms by which price increases are translated into trade performance. U.S. export and import price indexes are available for certain industry groups for the period of interest. These indexes could be used as a source of information to compare with the price increases suggested by the defense-competing metric. This comparison would indicate whether the export prices did increase as a result of defense spending. If export prices did increase, these indexes could also be used to examine the effects of the price increases on the trade performance of industries using our trade metrics.

A third follow-on effort would be to review the data from previous increases in defense spending such as the Vietnam buildup to look for similar effects. This is a useful comparison, since one key question raised by the findings of this research is whether the recession that occurred during the early 1980s might have counteracted the effects of defense spending. Since the defense spending for the Vietnam War occurred during a period of relatively high-capacity utilization, it would be valuable to apply the current methods and measures to that situation.

Finally, the mixed results of the tests for positive effects of defense spending suggest that there may be some mechanism by which defense spending might improve trade performance. This study generated some of the data and performance measures that made these tests possible. However, a more rigorous test of this hypothesis would be necessary to determine with any confidence that defense spending did have a positive effect on trade performance. Further research might also provide other explanations why defense spending might improve the trade performance of an industry.

# Appendix A

## DATA SOURCES FOR THE DEFENSE-COMPETING METRIC

The data used in this report are of four types: defense spending data, data on intraindustry sales (input-output tables), industry employment data (labor requirements matrix), and elasticity data. The sources for these four types of data are described in detail in this appendix.

### DEFENSE SPENDING DATA

Two different data sources were used for the procurement and the RDT&E budget figures. The DMS series of budget reports[1] were used for the procurement component of this information. For example, the FY 1982 defense procurement budget contains the outlay data at the level of detail necessary to allow conversion to detailed industry categories. Table A.1 shows an example of the data as provided in the budget reports.[2]

**Table A.1**

**Defense Procurement Budget (in millions of dollars)**

| Item | FY90 | FY80 | FY81 |
|---|---|---|---|
| Army | | | |
| Aircraft procurement | | | |
| Fixed wing | | | |
| C-12A cargo | — | 12.2 | — |
| RC-12 guardrail | — | — | — |
| Rotary | | | |
| AH-1S attack helicopter | 116.5 | 29.5 | — |
| CH-47C, D | 33.0 | — | — |
| UH-60A Black Hawk | 343.8 | 339.0 | 288.5 |

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[1] DMS (1980). Similar reports were used for other years of the defense buildup.

[2] DMS (1980), p. 5.

The RDT&E data were not required at the same level of detail for conversion to industry categories. As a result, service-level data were used, and these data were available in the *Budget of the United States Government*, Fiscal Year 1982, Appendix.[3] An example of the data from this source is shown in Table A.2.[4]

These two sources of data specify the dollar amounts of spending for the two accounts for 1980 and 1983. However, for these data to be useful for industry analysis, the dollar amounts by budget category had to be converted to dollars by industry category. This conversion is made possible with the defense translator tables. Translator tables allocating outlays for particular defense programs to specific industrial sectors have been created by the Office of the Secretary of Defense and the Institute for Defense Analysis (IDA) for the major procurement and RDT&E accounts. For the purposes of this report, 15 of these translator tables were used. Each table includes from 1 to 12 categories of defense spending.[5] A section of one of the translator tables is shown in Table A.3.

The figures from the two sources of budget data are entered in the top row of the table. Each dollar amount at the top of the column is then divided into industry spending based on the percentages below. For example, 13 percent of the $345 million budget for space programs goes for purchases from the missile industry, industry code 45. Total purchases from the guided missile industry resulting from space programs and other components (columns) of the Air Force missiles translator table amount to $531 million. The column labeled totals

**Table A.2**

**Defense RDT&E Budget**

| Research, development, test, and evaluation, Army | | |
|---|---|---|
| | Program and financing (in thousands of dollars) | |
| | Obligations | |
| | 1980 Actual | 1981 estimate |
| Program by activities ... | | |
| ... | | |
| 90.00 outlays | 2,707,031 | 2,941,000 |

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[3] For example, the data for 1980 outlays were available in the *1982 Budget Appendix*, pp. I-G40 to I-G44. Line 90 (outlays) was used consistently. Similarly, 1983 outlays were found in the 1985 budget.

[4] *1982 Budget Appendix*, pp. I-G40 to I-G44.

[5] These categories are based on those used in Thomas et al. (1984).

### Table A.3

### Air Force Missiles Translator Table (in millions of dollars)

| Industry Code | Industry | Totals | MX Missile | ... | Tactical Missiles | Space Programs |
|---|---|---|---|---|---|---|
| | | | **$0** | ... | **$240** | **$345** |
| | | | 0% | | 0% | 0% |
| 45 | Missiles | $531 | 28% | ... | 28% | 13% |
| 46 | Ammunition | $10 | 0% | ... | 2% | 0% |
| 161 | Chemicals | $34 | 11% | ... | 6% | 5% |
| 271 | Cutting tools | $77 | 1% | ... | 0% | 0% |
| 272 | Forming tools | $22 | 0% | ... | 0% | 0% |
| ... | ... | ... | ... | ... | ... | ... |
| 367 | Air transport | $3 | 2% | | 2% | 2% |
| | | | 100% | | 100% | 100% |

shows the total direct defense spending in each industry along the left olumn. (The totals in this excerpt of the entire table do not add, since only a few of the columns and rows are shown.)

An additional set of tables totals the purchases from each of the various translator tables to produce a single list of defense purchases by industry. The industry codes used in the translator tables are similar to the four-digit SIC. However, the four-digit SIC codes contain more industry detail than the other data sources used in this analysis. As a result, increases in spending by four-digit SIC code must be converted to the industry classification required for the next step in the process, the input-output classification system. A concordance was created that added the totals for each four-digit detailed SIC industry that is included in an input-output industry. For example, industry codes 45 and 46 shown in the above table, missiles and ammunition, were both allocated to the input-output industry 13, "ordnance and accessories."

This process was repeated for 1980 and 1983. The difference between the two columns of figures is the increase in defense spending in the year 1983 over the base year 1980. It is this additional demand that is traced through the economy.

## INPUT-OUTPUT TABLES

The second type of data used for this project is the summary input-output (I-O) tables of the U.S. economy, produced by the Bureau of

Economic Analysis, U.S. Department of Commerce.[6] Five different tables are produced for each year: the make table, the use table, the direct requirements table, and the commodity by commodity and the commodity by industry total requirements tables. These summary-level[7] tables divide the economy into 79 industries.

The use table is one of the two tables used in this analysis. It shows the value of each commodity used by each industry, with the rows showing the distribution of output for the commodity and columns showing the composition of inputs to an industry. For example, the entry in the row *i*, column *j* of the use table shows the amount of intermediate inputs required by industry *j* from industry *i*. Additional columns of the use table provide the data regarding the composition of final demand. These columns provide an accounting of each industry's output broken down into intermediate use, personal consumption expenditures, gross private fixed investment, exports, imports, and federal and state/local government purchases. The 1981 table was used for the figures on final demand.[8] A section of the use table showing the final demand is shown in Table A.4.[9]

**Table A.4**

**Input-Output Use Table (in millions of dollars)**

| Industry | Personal Consumption | Gross Private Fixed Investment | Exports | Government Purchases |
|---|---|---|---|---|
| ... | | | | |
| Electronic components | 529 | 35 | 2468 | 775 |
| Electrical machinery | 2003 | 1491 | 859 | 305 |
| Motor vehicles | 46124 | 30854 | 10963 | 3026 |
| Aircraft and parts | 427 | 2777 | 7159 | 9803 |
| ... | | | | |

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[6] For a complete description of the summary input-output tables, see, for example, "The Input-Output Structure of the U.S. Economy, 1977" (1984). More detailed input-output tables are available from the Department of Commerce with considerably more industry detail. However, these tables offer few advantages for this project, since supporting data are not available at a similar level of detail.

[7] The chief advantage to using the summary-level tables for this historical research is that the set of tables were available for the years of interest for the research. Detailed tables are available only for census years, and then with considerable delay.

[8] Unlike the coefficients in the direct or total requirements tables, the values in the columns representing final demand change significantly from year to year.

[9] *Survey of Current Business*, May 1984, p. 57.

The commodity by industry total requirements table was also used for this analysis. Each column of the table shows the inputs—both direct and indirect—required from each industry named at the beginning of the row for each dollar of output for the industry named at the top of the column. A section of the total requirements table is presented as Table A.5.[10]

For example, this table shows that for each dollar of final demand in the electrical machinery industry, 4.3 cents of direct and indirect spending is generated in the electronic components industry. The coefficients presented in this table allow the total effect of defense spending increases to be estimated, including not only the direct defense purchases from industries but the additional purchases that are generated by the defense expenditure. For the purposes of this research, the total requirements table also allows estimation of the total labor requirements generated by defense spending.[11]

## EMPLOYMENT DATA

The third type of data that are required for this analysis are data regarding the pattern and the level of employment by occupation and by industry. The Department of Labor has prepared the National Occupational Employment Matrix, a detailed matrix that describes the pattern of employment in the United States for 1986. This matrix is similar to the I-O use table except that the requirements by SIC industry are stated in terms of employees in various occupations rather than intermediate inputs. A section of the employment matrix is included as Table A.6.

### Table A.5

### Input-Output Total Requirements Table

| Industry | ... | Electronic Components | Electrical Machinery | Motor Vehicles | Aircraft & Parts | ... |
|---|---|---|---|---|---|---|
| ... | ... | ... | ... | ... | ... | ... |
| Electronic components | ... | 1.034 | .043 | .007 | .037 | ... |
| Electrical machinery | ... | .003 | .964 | .024 | .005 | ... |
| Motor vehicles | ... | .005 | .035 | 1.348 | ... | ... |
| Aircraft and parts | ... | .004 | .001 | .003 | 1.171 | ... |
| ... | ... | ... | ... | ... | ... | ... |

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[10] *Survey of Current Business*, May 1984, pp. 76–77.

[11] The total requirements table corresponds to the matrix $(I-A)^{-1}$ in Eq. (1b), Sec. 2.

## Table A.6

## Labor Requirements Matrix

|  |  | SIC Industry |  |  |  |  |
|---|---|---|---|---|---|---|
| Occupation |  | 371 Motor Vehicles | 372 Aircraft & Parts | 376 Guided Missiles | 379 Misc. Transport Equipment |  |
| ... | ... | ... | ... | ... | ... | ... |
| Aircraft assemblers, precision | ... | 746 | 7055 | 2515 | 691 | ... |
| Electrical and electronic equipment assemblers, precision | ... | 746 | 2838 | 645 | 691 | ... |
| Electromechanical equipment assemblers, precision | ... | 0 | 0 | 0 | 0 | ... |
| Fitters, structural metal, precision | ... | 4634 | 2024 | 645 | 340 | ... |
| Machinery builders and other precision machine assemblers | ... | 1743 | 5978 | 645 | 283 | ... |
| ... | ... | ... | ... | ... | ... | ... |

Each SIC industry column shows the number of employees in each occupational category represented by the rows. The occupational titles are highly detailed in this matrix; the full matrix contains 479 occupations (rows) and 236 industries (columns). The industries along the top coincide with the SIC classification system.

For this analysis, data had to be converted from numbers of workers (shown in Table A.6) into workers per million dollars of industry output. The resulting table is similar to the total requirements table shown in Table A.5, where each element is a coefficient representing the amount of input—in this case labor input—required from the occupational category (row) for each dollar of industry final demand represented by the column.

This modification was accomplished by collecting industry output figures for the year of the employment table. The majority of the output data by SIC code are available in the *Annual Survey of Manufactures* for 1986, published by the Bureau of the Census. The remaining industries are found in a variety of other sources, including the Census Bureau's *Census of Wholesale Trade*, *Census of Retail Trade*, and *Census of Service Industries*; the Department of Commerce's *U.S.*

*Industrial Outlook*, and *Business Statistics* published by the Bureau of Economic Analysis.

In most cases, a close match is possible between the SIC codes that are included in the occupational matrix and the SIC codes in those publications. In certain service industries, output figures are not available at the highly detailed industry level, and in those cases, we have aggregated industries (columns) to the level of available data.

## Identifying Supply-Constrained Occupations

One assumption of the analysis is that growth in the labor force is severely limited in the short run. This assumption is embodied in the model as supply elasticities of zero for labor occupations. This assumption is more realistic for some occupations than for others, and as a result, we have tried to differentiate between occupations where the supply appears to be inelastic and those occupations where the supply appears to be more elastic. It is beyond the scope of this project to calculate actual supply elasticities for the 479 occupations, but it is possible to make a step in this direction by using information included in the Labor Department's *Occupational Outlook Handbook*,[12] the companion source to the Labor Department's occupational matrix.

The *Handbook* has detailed descriptions of most of the occupations used in the calculations, and each of these descriptions includes a section on "training, other qualifications, and advancement." To determine which occupations might be more realistically described as having a zero elasticity in the short run, three specific criteria were used to identify those jobs that might be characterized by inelastic supply:

1. Education: The purpose of this criterion is to identify occupations that require some form of specific educational training. Indicators of such requirements might include a mention of a specific course of study or degree at the bachelor's level or, more commonly, some advanced vocational training or a graduate degree. For example, engineering occupations were counted as having a specific education requirement because of the following: "A bachelor's degree in engineering is generally acceptable for beginning engineering jobs" (p. 60), or for psychologists: "A doctoral degree is often required for employment as a psychologist" (p. 105). However, specific educational training does not appear to be a prerequisite for securities and financial services workers,

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[12] U.S. Department of Labor (1986).

based on the following description: "A college education is increasingly important" (p. 264).

2. Experience: This criterion identifies occupations with a specific mention of some form of apprenticeship or work requirement. A mention of informal on-the-job training was not considered sufficient for identifying an occupation as requiring specific work experience. Rather, we required a mention of some sort of formal experience needed in the particular job. For example, electricians are counted as having a specific work experience requirement because of the following: "Most training authorities recommend the completion of a 4-year apprenticeship as the best way to learn the electrical trade" (p. 388). However, bank officers and managers do not appear to have the same work experience requirement: "Many bank management positions are filled by promoting technically skilled personnel who have demonstrated the potential for increased responsibilities" (p. 27).
3. Licensing: The third criterion used was a requirement for some form of government license or certification procedure based on specialized training. For example, aircraft mechanics and engine specialists are considered to be in inelastic supply because of the following: "The majority of mechanics who work on civilian aircraft are licensed by the FAA as 'airframe mechanics,' 'powerplant mechanics,' or 'aircraft inspectors.' The FAA requires at least 18 months of work experience for an airframe or powerplant license" (p. 335). However, licenses such as chauffeur's licenses for driving trucks or taxis were not considered as sufficient to indicate that workers in these occupations might be in inelastic supply.

### Results Using Supply-Constrained Occupations

Table A.7 lists the occupations that have a specific educational, experience, or licensing requirement based on the criteria above. There are 67 occupations requiring specific educational training, 64 with specific work experience requirements, and 32 with licensing requirements. The number of occupations with one or more of these requirements is 130.

## FINAL DEMAND ELASTICITIES

The final type of data used in this analysis is the set of price elasticities for final demand for the industries in the U.S. economy. The

## Table A.7

## Supply-Constrained Occupations

| Occupation | Education | Experience | License |
|---|---|---|---|
| Education administrators | * | * | * |
| Public administration chief executives, legislative, and general administration | * | * | |
| Accountants and auditors | * | | * |
| Inspectors and compliance officers, except construction | | | * |
| Construction and building inspectors | | | * |
| Management analysts | * | | |
| Tax examiners, collectors, and revenue agents | * | | |
| Underwriters | * | | |
| Aeronautical and astronautical engineers | * | | |
| Chemical engineers | * | | |
| Civil engineers, including traffic engineers | * | | |
| Electrical and electronics engineers | * | | |
| Industrial engineers, except safety engineers | * | | |
| Mechanical engineers | * | | |
| Metallurgists and metal, ceramic, and material engineers | * | | |
| Mining engineers, including mine safety engineers | * | | |
| Nuclear engineers | * | | |
| Petroleum engineers | * | | |
| All other engineers | * | | |
| Architects, except landscape and marine | | * | * |
| Surveyors | | * | * |
| Agricultural and food scientists | * | | |
| Biological scientists | * | | |
| Foresters and conservation scientists | * | | |
| All other life scientists | * | | |
| Statisticians | * | | |
| Mathematicians and all other mathematical scientists | * | | |
| Operations and systems researchers | * | | |
| Chemists | * | | |
| Geologists, geophysicists, and oceanographers | * | | |
| Meteorologists | * | | |
| Physicists and astronomers | * | | |
| All other physical scientists | * | | |
| Economists | * | | |
| Psychologists | * | | |
| Urban and regional planners | * | | |
| All other social scientists | * | | |
| Clergy | * | * | |

## Table A.7—continued

| Occupation | Education | Experience | License |
|---|---|---|---|
| Judges, magistrates, and other judicial workers | * | | |
| Lawyers | * | | * |
| Teachers, preschool | | | |
| Teachers, kindergarten and elementary | * | | * |
| Teachers, secondary school | * | | * |
| College and university faculty | * | | * |
| Teachers and instructors, vocational education and training | | | * |
| Librarians, professional | * | | |
| Counselors | * | | |
| Dentists | * | | * |
| Optometrists | * | | * |
| Pharmacists | * | | * |
| Podiatrists | * | | * |
| Physicians and surgeons | * | | * |
| Registered nurses | * | | * |
| Occupational therapists | | | * |
| Physical therapists | | | * |
| Speech pathologists and audiologists | * | | |
| Veterinarians and veterinary inspectors | * | | * |
| Dental hygienists | | | * |
| Emergency medical technicians | * | | |
| Licensed practical nurses | * | | * |
| Surgical technicians | * | | |
| Electrical and electronic technicians/ technologists | * | | |
| All other engineering technicians and technologists | * | | |
| Physical and life science technicians/ technologists and mathematical technicians | * | | |
| Air traffic controllers | | | * |
| Broadcast technicians | | | * |
| Programmers, numerical, tool, and process control | | * | |
| Brokers, real estate | | | * |
| Sales agents, real estate | | | * |
| Real estate appraisers | | | * |
| Electricians | | * | |
| Central office and PBX installers and repairers | * | * | |
| Frame wirers, central office | * | * | |
| Radio mechanics | * | * | |
| Signal or track switch maintainers | | | |
| All other communications equipment mechanics, installers, and repairers | * | * | |
| Data processing equipment repairers | * | * | |

## Table A.7—continued

| Occupation | Education | Experience | License |
|---|---|---|---|
| Electrical powerline installers and repairers | * | * | |
| Electronic home entertainment equipment repairers | * | * | |
| Electronics repairers, commercial and industrial equipment | * | * | |
| Station installers and repairers, telephone | * | * | |
| Telephone and cable TV line installers and repairers | | | |
| All other electrical and electronic equipment mechanics, installers, and repairers | * | * | |
| Industrial machinery mechanics | * | * | |
| Aircraft engine specialists | | * | * |
| Aircraft mechanics | | * | * |
| Boilermakers | | * | |
| Jewelers and silversmiths | | * | |
| Machinists | | * | |
| Shipfitters | | * | |
| Tool and die makers | | * | |
| All other precision metal workers | | * | |
| Numerical control machine tool operators and tenders, metal/plastic | | * | |
| Combination machine tool setters, set-up operators, operators, and tenders | | * | |
| Drilling machine tool setters and set-up operators, metal and plastic | | * | |
| Grinding machine setters and set-up operators, metal and plastic | | * | |
| Lathe machine tool setters and set-up operators, metal and plastic | | * | |
| Punching machine setters and set-up operators, metal and plastic | | * | |
| Soldering and brazing machine operators and setters | | * | |
| Welding machine setters, operators, and tenders | | * | |
| Electric plating machine operators and tenders, setters, and set-up operators, metal and plastic | | * | |
| Heating equipment setters and set-up operators, metal and plastic | | * | |
| Metal molding machine operators and tenders, setters and set-up operators | | * | |
| Nonelectric plating machine operators and tenders, setters and set-up operators, metal and plastic | | * | |
| Plastic molding machine operators and tenders, setters and set-up operators | | * | |

## Table A.7—continued

| Occupation | Education | Experience | License |
|---|---|---|---|
| All other metal/plastic machine setters, operators, and related workers | | * | |
| Bindery machine operators, setters and set-up operators | | * | |
| Letterpress setters and set-up operators | | * | |
| Offset lithographic press setters and set-up operators | | * | |
| Printing press machine setters, operators and tenders | | * | |
| All other printing press setters and set-up operators | | * | |
| Screen printing machine setters and set-up operators | | * | |
| Head sawyers and sawing machine operators and tenders, setters and set-up operators | | * | |
| Woodworking machine operators and tenders, setters and set-up operators | | * | |
| Cutting and slicing machine setters, operators and tenders | | * | |
| Dairy processing equipment operators, including setters | | * | |
| Electronic semiconductor processors | | * | |
| Extruding and forming machine setters, operators and tenders | | * | |
| Painting machine operators, tenders, setters, and set-up operators | | * | |
| Paper goods machine setters and set-up operators | | * | |
| All other machine operators, tenders, setters, and set-up operators | | * | |
| Aircraft assemblers, precision | | * | |
| Electrical and electronic equipment assemblers, precision | | * | |
| Electromechanical equipment assemblers, precision | | * | |
| Fitters, structural metal, precision | | * | |
| Machine builders and other precision machine assemblers | | * | |
| Electrical and electronic assemblers | | * | |
| Aircraft pilots and flight engineers | | * | * |
| Locomotive engineers | | | * |
| Captains and pilots, ship | | * | * |
| Ship engineers | | * | |

analysis assumes fixed coefficient production processes and inelastic supplies of labor. As a result, increased defense demand for workers can be met only by decreases in production for final demand. The final demand categories are personal consumption expenditures, gross private fixed investment, exports, and government purchases (see Table A.4). Elasticities for each of these final demand categories are necessary.

## Personal Consumption Expenditures

This category is especially important as a percentage of the output of food products, apparel, and other consumer good industries. Two sources provided suitable, although somewhat different, estimates of the elasticities of final demand. Mansur and Whalley[13] present central tendency values for own-price elasticities of household demand functions in a recent book on the construction of general equilibrium models. All are uncompensated own-price elasticities.[14] Each of the 79 I-O industries used in this analysis was assigned on the basis of industry name to one of the 23 industries for which Mansur and Whalley provide elasticity estimates (see Table A.8).

An additional set of own-price elasticities in consumption is presented by Petri (1983). The elasticities in this source are significantly lower across the board and include estimates for 19 industries. The elasticity estimates from Petri and Mansur and Whalley are similar, however, in areas where personal consumption expenditures are a significant share of industry output.

## Exports

Estimates of export price elasticities are not as common as estimates of import price elasticities and, as a result, there was not a high level of detail in the number of industries covered. The best available data are provided in Stern and Schumacher (1976). These estimates divide export industries into six groups by Standard International

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[13] Mansur and Whalley (1984), p. 109.

[14] Uncompensated demand elasticities reflect the change in demand from changes in price uncompensated for the resulting change in income (Marshallian demand function). The compensated demand function (Hicksian) varies both price and income to maintain the consumer at a fixed level of utility.

## Table A.8

## Personal Consumption Elasticities

| Industry | Own-Price Elasticity | Number of Studies | Variance |
|---|---|---|---|
| Agriculture and fishing | 0.468 | 86 | 0.07 |
| Coal mining | 0.950 | 3 | 0.76 |
| Other mining | 0.609 | 6 | 0.13 |
| Food | 0.494 | 72 | 0.13 |
| Drink | 0.607 | 32 | 0.16 |
| Tobacco | 0.507 | 19 | 0.10 |
| Mineral oils | 0.609 | 6 | 0.13 |
| Other petroleum products | 1.589 | 8 | 0.90 |
| Chemicals | 0.724 | 5 | 0.05 |
| Metals | 1.083 | 51 | 0.48 |
| Mechanical engineering | 1.005 | 45 | 0.48 |
| Instruments | 0.972 | 42 | 0.49 |
| *Electrical engineering* | 1.06 | 50 | 0.44 |
| Vehicles | 0.985 | 51 | 0.44 |
| Clothing | 0.458 | 61 | 0.18 |
| Wood, furniture, etc. | 0.969 | 53 | 0.33 |
| Paper, printing, publishing | 0.362 | 11 | 0.02 |
| Other manufacturing | 0.592 | 38 | 0.09 |
| Utilities | 0.659 | 20 | 0.10 |
| Transport | 0.977 | 28 | 0.23 |
| Banking and insurance | 0.642 | 4 | 0.04 |
| Housing services | 0.505 | 53 | 0.29 |
| Professional services | 0.961 | 50 | 0.48 |

SOURCE: Mansur and Whalley (1984), p. 109. The second and third columns indicate the quality of the estimates. These additional data were not used in this research.

Trade Classification (SITC) system. Additional detail is available from Houthakker and Magee (1969). These elasticity estimates are more detailed, but did not differ greatly from the estimates presented by Stern and Schumacher. Agricultural exports tended to have relatively low elasticities ($0.5 < |\varepsilon| < 1$), whereas elasticities for manufactured goods were generally higher ($1 < |\varepsilon| < 2$).

### Government Purchases

This category includes both federal government purchases and state and local government purchases. No readily available sources for government purchase elasticities could be found, so a range of elasticities have been incorporated into our analysis. The first set of calculations incorporates zero elasticities for all government purchases, which is the lower bound of the range of elasticities. Zero elasticities are consistent with government purchases that must meet fixed requirements and are therefore completely insensitive to price. A second case incorporated all unit elasticities, on the assumption that the government purchases only as much as the budget allows. A third scenario applies different elasticities to different classes of government spending. We assume elasticities of 0 for defense purchases and 1 for state and local maintenance-type purchases. Health purchases were also given an elasticity of 0, since these are often determined by entitlement rather than by a fixed budget allocation.

### Gross Private Fixed Investment

The fourth component of final demand is Gross Private Fixed Investment (GPFI). The entire output of the construction industry is considered GPFI, as is a smaller share of the output of a number of service industries. Although GPFI is not considered an intermediate input in the I-O tables, the fixed coefficient nature of the model that we are using would also suggest that the fixed costs of production are also part of the production recipe. As a result, elasticity values of 0 were assumed for each of these investment components.

## CONCORDANCES

The final type of data used in the calculation of the defense-competing metric is the set of concordances and crosswalks necessary to convert from one classification system to another. The 400-industry detail reflected in the defense translator tables and the 236-industry employment matrix had to be converted to the 79-industry I-O classification format. This involved using a version of a published table of the SIC to input-output concordance,[15] which allowed many SIC groups to be incorporated into a single I-O industry.[16]

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[15] *Survey of Current Business*, May 1984, pp. 80–84.

[16] Concordances can be of four types, one-to-one, many-to-one, one-to-many, and many-to-many. The first is ideal and entails no loss of data quality or detail. Many-to-one concordances lead to a loss in data detail but have the advantage that the detailed data can be added or averaged in the new category so that there is no loss in data quality. For example, defense purchases from "truck and bus bodies" and "automobiles" can be added and will accurately reflect the defense purchases of the broader category of "motor vehicles." On the other hand, if an aggregated industry must be divided into subindustries as in a one-to-many concordance, there is no way to divide the total dollar value (unless additional information is available) except by assuming that the detailed categories are equal, which is an unacceptable assumption. In other situations, the one-to-many concordance does not lead to a dead end. For example, when there is limited detail on elasticity data, it is possible to assume that indi-

It was also necessary to use data with various levels of SIC detail, such as in the collection of output figures to match the 236 industries represented in the employment matrix. In some cases, the detail was greater than needed, and in others, the detail was less than required. Finally, some data sources have only a fraction of the data detail of the input-output tables. This was the case with most of the elasticity data. In these cases, one elasticity category was used for many I-O categories.

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vidual industries within a more aggregated industry have a similar elasticity value. Many-to-many concordances occur when there is little coordination between the data categories.

# Appendix B

## CALCULATIONS FOR THE DEFENSE-COMPETING METRIC

This appendix describes the calculations required for the defense-competing metric. The metric is reproduced here from Eq. (10) in Sec. 2.

$$\frac{P_i}{P_i} = \sum_j C_{ji} \frac{\sum_k C_{jk} d_k}{\sum_k C_{jk}^2 \varepsilon_k F_k} ,$$

where

$p_i / P_i$ = the percentage change in output price for industry $i$,

$C_{ji}$ = the amount of labor of type $j$ needed to produce a unit of good $i$, including all of the labor necessary to produce all of the intermediate products needed to produce $i$,

$d_k$ = the change in defense demand for goods from industry $k$,

$F_k$ = the total final demand for good $k$, and

$\varepsilon_k$ = the negative of the own-price elasticity of final demand for good $k$.

Three components are computed separately before being incorporated into the model: $d_k$, the changes in defense demand; $C_{jk}$, the total labor requirements matrix; and $\varepsilon_k$, the weighted final demand elasticity for each of the 79 industries. This appendix documents both the concordance programs that are necessary to convert the data sources to compatible forms as well as the actual calculations that are performed.

### THE INCREASE IN DEFENSE SPENDING

Equation (B.1) shows the steps required in the calculation of the vector $\boldsymbol{d}$.

$$\boldsymbol{d} = \left(\boldsymbol{k} \bullet \left(\boldsymbol{T} \bullet \boldsymbol{b}^{83}\right)\right) - \left(\boldsymbol{K} \bullet \left(\boldsymbol{T} \bullet \boldsymbol{b}^{80}\right)\right), \tag{B.1}$$

where

$\boldsymbol{d}$ = the vector of increases in defense spending from 1980 to 1983 by industry for each of 79 industries,

$\boldsymbol{K}$ = a 79 x 400 concordance matrix that converts four-digit SIC industries into I-O industries,

$\boldsymbol{T}$ = the 400 x 102 translator table that convert budget categories to DRI industry categories, and

$\boldsymbol{b}^{83}$ and $\boldsymbol{b}^{80}$ = (102 x 1) vectors of the defense budget outlays for 1983 and 1980.

As mentioned above, the first step is to convert the procurement and RDT&E spending from the defense budget categories into industry categories (represented by the calculations inside the nested parentheses). This is performed by multiplying the budget figures $\boldsymbol{b}$ by the translator table $\boldsymbol{T}$. The procurement and RDT&E accounts are divided into 102 different spending categories within 15 sections. Each section accounts for a particular type of spending within a service. For example, the Navy has sections for aircraft procurement, weapons procurement, and shipbuilding and conversion. Within each section are the actual categories of defense spending, either single large weapon systems, or groupings of weapons or activities in a single area.[1] There are a total of 102 different categories.

The next step is a concordance program that converts the output of the translator tables by detailed industry code into dollars by I-O category. This concordance program can be represented as the product of the 79 x 400 matrix $\boldsymbol{K}$ and the 400 x 1 vector $(\boldsymbol{T} \bullet \boldsymbol{b})$. The $\boldsymbol{K}$ matrix contains only zeros and ones, and the ones indicate those DRI industries (columns) that correspond to the I-O industries. The product of $\boldsymbol{K}$ and $(\boldsymbol{T} \bullet \boldsymbol{b}^{83})$ could be referred to as $\boldsymbol{d}^{83}$, which represents the direct defense spending resulting from the procurement and RDT&E accounts in 1983 for each of 79 I-O industries. The final step in the calculation is to subtract the 1980 from the 1983 $(\boldsymbol{d}^{83} - \boldsymbol{d}^{80} = \boldsymbol{d})$ spending to determine the increase in spending by industry for that period, although not a cumulative increase in spending. These listings of industries that supply the direct requirements of the

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[1] Each section is a single table in the source document. For an example, see App. A.

Department of Defense are standard outputs of input-output analysis.[2]

## THE TOTAL LABOR REQUIREMENTS MATRIX

The total labor requirements matrix **C** that appear in the metric in three positions also requires a series of steps for calculation. The steps are shown in Eq. (2) and described below.

$$C = \left(M \bullet (B \bullet Q)'\right)' \bullet (I - A)^{-1} \qquad \text{(B.2)}$$

where

$C$ = the 479 x 79 total labor requirements matrix,

$M$ = a 79 x 225 concordance matrix that converts the SIC industries of the national employment matrix into I-O industries,

$B$ = the 479 x 225 original occupational matrix supplied by the Department of Labor,

$Q$ = a 225 x 225 diagonal matrix where each element is 1/(total industry output), and

$(I - A)^{-1}$ = the 79 x 79 total requirements matrix of the input-output tables as published by the Bureau of Economic Analysis.

The original labor matrix $B$ is the occupational employment matrix provided by the Department of Labor for 1986. Each element in this matrix is an estimate of the number of workers in each occupation (row) for each industry (column). The source matrix consists of summary (105) and detail (479) occupations and summary (66) and detail (236) industries. For this project, a combination of summary and detailed industries was used with the detailed occupations. This resulted in a matrix of 479 detailed occupations for 225 industries.

Several modifications were necessary for this matrix to be useful for this project. First, the elements in the matrix had to be converted from numbers of workers to workers per million dollars of industry output. The second step was to convert the industries in the labor matrix to the industries according to the input-output classification.

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[2] For examples of this use of input-output analyses, see Leontief (1965), or more recently, Henry and Oliver (1987).

The processes used to make these modifications are described in detail below.

## Conversion to Workers per Million Dollars of Output

The conversion required an estimate of the dollar value of output for each of the 225 industries for the year 1986. In each case, the first step was to ensure a close match between the definition of the industry used in the labor requirements matrix and in the source that was used for the dollar value of output. The SIC equivalents of the labor requirements matrix industry categories were used to look up the value of industry output. This conversion is represented in Eq. (B.2) as multiplication of $\boldsymbol{B}$ by $\boldsymbol{Q}$, a diagonal matrix with entries for each industry of 1/(total industry output). These figures were checked using estimates of the employment figures (if available) in the dollar value source[3] against the total for each labor matrix industry. When the employment figures were not available for comparison, the employment per dollar ratio was checked to determine if it was in line with prior information. For example, prior information indicated that all industries would have a ratio of between one worker per million dollars of output (highly capital intensive industries such as petroleum refining) and 50 workers per million dollars of output (highly labor intensive services such as barber shops and newsstands).

In a few industries, data were not available to allow the use of the full detail available in the labor requirements matrix. These included construction, transportation, communication, utilities, and the industries included in finance, insurance, and real estate. In these cases, the broader industry definitions and the corresponding vectors of occupational employment were used from the labor matrix, and output estimates of these broader aggregates were used from the sources listed in App. A.

## Convert to the 79 Industry I-O Classification System

This step requires two types of information:

- The concordance between the labor matrix 225 industry classification and the I-O 79 industry classification system.

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[3] Certain Census publications include employment data. The Bureau of Labor Statistics, *Supplement to Employment and Earnings*, August 1988, was also used.

- The weights to be used when combinations of labor matrix industries map to the same I-O industry.

The concordance between the 225 detailed SIC industries and the 79 I-O industries usually involved combining a number of the detailed SIC industries into the more aggregated I-O industries. Although this involves a loss of industry detail, the quality of the resulting coefficients for the larger industry accurately represents the combined set of individual industries. This was accomplished by appropriately weighting the detailed SIC industries to create the new aggregate I-O industry.

For example, if the separate missiles (SIC 3761) and ammunition (SIC 3482) industries account for 75 percent and 25 percent, respectively, of the aggregate ordnance I-O industry, the labor requirements coefficients of the ordnance industry should reflect the larger size of the missiles industry. This is accomplished by creating a new coefficient for each labor category that is 0.75 times the missiles coefficient plus 0.25 times the ammunition coefficient. Although some industry detail is lost in this concordance, the occupational requirements per million dollars will remain accurate for the aggregate industry.

The many-to-one concordance for all industries is accomplished through matrix multiplication. In this case, the entries in the concordance matrix include zeros, ones, and fractions where more than one SIC industry maps into one I-O industry. The fraction is based on the share of the individual industry's dollar value of the total value of industries that map into the I-O industry. Each row of the ***M*** concordance matrix will sum to one, so that the new I-O industry row will be a weighted combination of one or more SIC industries.[4]

In cases where the concordance between the industries is clear, the total value of the labor industries mapping into the I-O industry was

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[4] If

$$\mathbf{K} = \begin{bmatrix} .5 & .5 & 0 & 0 \\ 0 & 0 & .9 & .1 \end{bmatrix}$$

and

$$(\mathbf{B} \cdot \mathbf{Q})' = \begin{bmatrix} 10 & 10 & 10 \\ 20 & 20 & 20 \\ 30 & 30 & 30 \\ 40 & 40 & 40 \end{bmatrix},$$

**then the product will be a 2 x 3 matrix where the first row is an average of the first and second rows of the latter matrix, and the second row is 0.9 times the third row and 0.1 times the final row, or**

$$\mathbf{K}(\mathbf{B} \cdot \mathbf{Q})' = \begin{bmatrix} 15 & 15 & 15 \\ 31 & 31 & 31 \end{bmatrix}.$$

approximately equal to the I-O value. However, in two industries—federal government and state/local government industries (I-O industries 78 and 79)—the values and the resulting number of employees in those industries are substantially different.[5] As a result of comparisons with other employment data sources such as the Labor Department's *Employment and Earnings*, these two columns were scaled upward.

### Additional Steps to Create the *C* Matrix

The steps outlined above lead to the creation of the $(M \cdot (B \cdot Q)')'$ matrix, which is 479 x 79. To create the **C** matrix, this matrix is multiplied by the $(I - A)^{-1}$ matrix, the total requirements matrix of the I-O tables. The result of this calculation is the **C** matrix, which represents the total labor requirements per million dollars of output for each of the 79 industries.

## CALCULATION OF A COMPOSITE ELASTICITY TIMES FINAL DEMAND

The third component that is computed separately is the set of products of industry final demand and the corresponding elasticities. The calculation is shown in Eq. (B.3) and described below.

$$\varepsilon_k = \sum_i \varepsilon_{ik} F_{ik} \, , \tag{B.3}$$

where

$\varepsilon_k$ = the elasticity of final demand for each of 79 industries,

$i$ = an index of the component of final demand, either personal consumption, gross private fixed investment, exports, or government purchases,

$\varepsilon_{ik}$ = the elasticity for the $i^{\text{th}}$ component of final demand for the $k^{\text{th}}$ industry, and

$F_{ik}$ = the dollar value of final demand for the $i^{\text{th}}$ component of final demand for the $k^{\text{th}}$ industry.

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[5] This was checked by multiplying the I-O dollar value and the sum of all the workers per dollar coefficients to get a total employment figure.

Final demand for each I-O industry was calculated as the sum of the following four categories of final demand:[6]

- Personal consumption expenditures ,
- Gross private fixed investment,
- Exports, and
- Government purchases.

Some combination of these different elasticities is appropriate for each of the 79 industries in the model, depending upon the composition of final demand. For example, in the electronic components industry (I-O 57), the final demands and the corresponding elasticities are the following:

**Table B.1**

**Calculating Elasticities of Final Demand**

| Component of Final Demand | Final Demand | | |
|---|---|---|---|
| | Component/Total $ | | Elasticity |
| Personal consumption | 1104/7492 | x | 1.1 |
| GPFI | 87/7492 | x | 0 |
| Exports | 5558/7492 | x | 1.2 |
| Government purchases | 1743/7492 | x | 0 |
| | Composite elasticity | | 1.05 |

Therefore, the elasticity of final demand used in the remainder of the calculations for the electronic components industry is 1.05.[7]

## COMBINING THE FOUR COMPONENTS

The final steps involve the actual computation of the defense metric, which is repeated below.

$$p_i = \sum_j C_{ji} \frac{\sum_k C_{jk} d_k}{\sum_k C_{jk}^2 \varepsilon_k F_k} .$$

This requires the three components described above: $d_k$, $C_{jk}$, $\varepsilon_k$, and a matrix $C^2{}_{jk}$ where each element is the square of the corresponding el-

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[6] This definition of final demand could also be calculated as "total final demand" – "imports" (column 95) – "change in business inventories" (column 93).

[7] This process was repeated using different estimates for personal consumption and government purchases elasticities as described in Sec. 2.

ement of $C_{jk}$. The calculation was performed in a series of steps, some of which produce intermediate results of interest.

The numerator of the metric can be considered the increase in demand for the 479 occupations resulting from the increased defense spending from 1980 to 1983. The denominator of this fraction roughly represents the availability of workers in each occupation. This availability depends upon the number of workers in specific occupations, since an increase in demand of 1000 workers will have a greater impact on a small highly specialized occupation than on one with numerous members. In addition, the availability depends upon the category of final demand where the nondefense workers are employed. If all the workers in a particular occupation are employed in industries with low elasticities of demand, this would indicate that wages would have to increase substantially before the additional defense needs were met. On the other hand, if the workers are employed in industries characterized by high price elasticities for final demand, the expected wage increases would be more modest.

The entire fraction is an indication of the impact of spending on occupations, which takes into account both the increased demand created by defense spending, the number of workers involved in production for final demand, and the elasticity of final demand for the sectors where those workers are employed. The full metric is simply the weighted sum of the occupational impacts for each industry.

# Appendix C

# ADDITIONAL DETAIL ON THE TRADE METRICS

This appendix details the properties of the trade performance metrics. In particular, it describes the circumstances in which each does or does not satisfy the three requirements noted in Sec. 3. The formulas for the three metrics are reproduced here from Sec. 3.

$$F_i = \frac{\dfrac{\Delta X_i}{X_i}}{\dfrac{X - \Delta X_i}{X - X_i}} - \frac{\dfrac{\Delta M_i}{M_i}}{\dfrac{M - \Delta M_i}{M - M_i}}$$

$$G_i = \frac{\dfrac{\Delta X_i}{X_i}}{\dfrac{\Delta X}{X}} - \frac{\dfrac{\Delta M_i}{M_i}}{\dfrac{\Delta M}{M}}$$

$$H_i = \text{rank}\,\frac{\Delta X_i}{X_i} - \text{rank}\,\frac{\Delta M_i}{M_i}$$

## INSENSITIVITY TO RELATIVE PRICE CHANGES

Suppose that there are no changes in the volumes of trade flows of any commodity. Suppose that the price of commodity $i$, both imports and exports, rises by $p_i$ and that the prices of all other commodities rise by $p$ percent. The first metric will yield a value of:

$$F_i = \frac{p_i}{p} - \frac{p_i}{p} = 0 ,$$

which is the desired result.

The second metric will produce a value of:

$$G_i = \frac{p_i}{p(1 + S_i) + p_i S_i} - \frac{p_i}{p(1 + T_i) + p_i T_i} .$$

This expression will equal zero exactly only in the unlikely case that the shares of imports and exports accounted for by the sector in question are identical. As long as the shares $S_i$ and $T_i$ are small, the value of the expression will be close to zero. Thus, as long as total imports and exports are sufficiently diverse that no one category accounts for more than a small fraction of the total, the second metric will approximately satisfy the condition of insensitivity to relative price changes.

Translating these percentage changes into ranks for the third metric:

| | Import and export value at time | |
|---|---|---|
| | t | t + 1 |
| Widgets | 1 | $p_i$ |
| All other | 1 | $p$ |

The metric will yield a value of:

$$H_i = 2 - 2 = 0 \; if \, p_i > p \; ,$$
$$H_i = 1 - 1 = 0 \; if \, p_i < p \; .$$

In both cases, the metric $H$ shows neutral trade performance.

## INSENSITIVITY TO UNIFORM GROWTH IN IMPORTS AND EXPORTS

U.S. trade flows were strongly influenced by economy-wide factors such as the value of the dollar and differences among relative growth rates in the United States compared with its trading partners. A suitable trade performance metric will be insensitive to those factors that effect all imports or exports.

Suppose that the value of exports in every category grows by $x$ percent and that the value of imports in every category grows by $y$ percent. The share of total import or export value accounted for by any commodity $i$ will be unchanged; that is,

$$\frac{\Delta X_i}{X} = 0$$

and

$$\frac{\Delta M_i}{M} = 0 \; .$$

In this case,

$$\frac{\Delta X}{X} = \frac{\Delta X - \Delta X_i}{X - X_i} = X$$

and

$$\frac{\Delta M}{M} = \frac{\Delta M - M_i}{M - M_i} = y ,$$

and both metrics produce the desired neutral value for any sector $i$:

$$F_i = G_i = \frac{x}{x} - \frac{y}{y} = 0 .$$

In the case of the third metric, if imports of all sectors grow by the same amount, all import industries will be tied with the same rank of $(n + 1)/2$, and if exports all grow by the same amount (even if different from the import growth), their ranks will be the same. Therefore, the metric will show a neutral result.

## INSENSITIVITY TO PRODUCT CLASSIFICATION

The classification of products for statistical purposes is arbitrary and should not affect the trade performance results. This is similar to the requirement above that the metric be insensitive to the scale of imports or exports. Imagine that a homogeneous category of products is divided into two new categories. Call these new categories category $i$ and category $j$. Since the products in the new categories are identical to each other, we would expect that

$$\frac{\Delta X_i}{X_i} = \frac{\Delta X_j}{X_j}$$

and

$$\frac{\Delta M_i}{M_i} = \frac{\Delta M_j}{M_j} . \qquad \text{(C.1)}$$

Let us consider first the second metric and the value it generates for the combined category. We will denote the value for this combined category $G_{i+j}$ Notice that the numerator of the first, or export, term of this metric will be:

$$\frac{\Delta\left(X_i + X_j\right)}{X_i + X_j} = \frac{\Delta X_i}{X_i}\frac{X_i}{\left(X_i + X_j\right)} + \frac{\Delta X_j}{X_j}\frac{X_j}{\left(X_i + X_j\right)} .$$

But this is just a weighted average of two terms, which by Eq. (C.1) are equal. Thus,

$$\frac{\Delta\left(X_i + X_j\right)}{X_i + X_j} = \frac{\Delta X_i}{X_i} = \frac{\Delta X_j}{X_j} . \tag{C.2}$$

Similarly,

$$\frac{\Delta\left(M_i + M_j\right)}{M_i + M_j} = \frac{\Delta M_i}{M_i} = \frac{\Delta M_j}{M_j} . \tag{C.3}$$

We may now write:

$$G_{i+j} = \frac{\dfrac{\Delta\left(X_i + X_j\right)}{X_i + X_j}}{\dfrac{\Delta X}{X}} - \frac{\dfrac{\Delta\left(M_i + M_j\right)}{M_i + M_j}}{\dfrac{\Delta M}{M}} .$$

Applying Eqs. (C.2) and (C.3) to the numerators of this expression, we have:

$$G_{i+j} = \frac{\dfrac{\Delta X_i}{X_i}}{\dfrac{\Delta X}{X}} - \frac{\dfrac{\Delta M_i}{M_i}}{\dfrac{\Delta M}{M}} = \frac{\dfrac{\Delta X_j}{X_j}}{\dfrac{\Delta X}{X}} - \frac{\dfrac{\Delta M_j}{M_j}}{\dfrac{\Delta M}{M}} ,$$

and

$$G_{i+j} = G_i = G_j .$$

Turning now to the first metric, we may write:

$$F_{i+j} = \frac{\dfrac{\Delta\left(X_i + X_j\right)}{X_i + X_j}}{\dfrac{\Delta X - \Delta\left(X_i + X_j\right)}{X - X_i - X_j}} - \frac{\dfrac{\Delta\left(M_i + M_j\right)}{M_i + M_j}}{\dfrac{\Delta M - \Delta\left(M_i + M_j\right)}{M - M_i - M_j}} \tag{C.4}$$

Note that if $S_i$ and $T_i$ are small,

$$\frac{\Delta X}{X} \approx \frac{\Delta X - X_i}{X - X_i}$$

and

$$\frac{\Delta M}{M} \approx \frac{\Delta M - \Delta M_i}{M - M_i} .$$

Using these approximations and applying Eqs. (C.2) and (C.3) to the numerators of Eq. (C.4) gives:

$$F_{i+j} \approx \frac{\dfrac{\Delta X_i}{X_i}}{\dfrac{\Delta X - \Delta X_i}{X - X_i}} - \frac{\dfrac{\Delta M_i}{M_i}}{\dfrac{\Delta M - \Delta M_i}{M - M_i}} = F_i .$$

Assuming that $S_j << 1$ and $T_j << 1$ also, we can perform a similar manipulation to show that

$$F_{i+j} \approx F_j .$$

Therefore, the two metrics meet this condition if trade is sufficiently diverse that no single sector accounts for more than a small share of total imports or total exports.

Finally, we will consider the sensitivity of the rank-order trade metric $H$ to changes in product classification. Suppose that the original $H_k$ = 10, resulting from an export rank of 60 and an import rank of 50. If this industry is split into two industries $i$ and $j$, the resulting export ranks of both will be 60.5, and the import ranks will both be 50.5. Therefore, $H_i$ = 10 and $H_j$ = 10, which meets the requirement.

The addition of the category may affect other industry results, however, since there is one additional category in the list. For example, if $H_m$ = 25 resulting from an export rank of 65 and an import rank of 40, $H_m'$ = 26, since the new rank will be based on an export rank of 66 and an import rank of 40.

We have now shown that while none of the proposed metrics meets all three of the conditions specified in Sec. 3, all three will satisfy them at least approximately if the trade is sufficiently diverse that no single sector accounts for more than a small share of either total imports or total exports.

# Appendix D

## REASONS FOR EXCLUDING NONMANUFACTURES FROM THE TRADE METRIC

All three trade performance metrics "normalize" growth in the value of imports and exports within a particular sector by comparing the industry growth rates to the growth rate of "all" (or "all" other) imports and exports. In actually calculating the metrics, though, a question arises over what should be included in "all" imports or "all" exports. Should we be normalizing sectoral trade growth by the growth of all merchandise trade, trade in both goods and services, trade in manufactures only, or some other subset of merchandise trade? Put another way, what should be included in our concept of "total" trade?

Our aim in normalizing sectoral rates of trade growth is to create metrics that reflect changes in the relative performance of import and export industries and that are insensitive to the effects of factors—such as exchange rate changes or the business cycle—that affect trade flows in all sectors. This aim provides a suggestion of what we should mean by "all." Exchange rates will influence primarily trade in manufactures. The prices of cars, computers, electronics, and other manufactured products generally reflect the costs of manufacturing these products. Because similar products manufactured in the United States and abroad are only imperfect substitutes for each other, prices for U.S. and foreign-made products will not always be the same. A weaker dollar will lower the price of U.S.-manufactured goods compared with similar foreign products, probably stimulating exports and discouraging imports.

In contrast, commodities—such as oil or grain—are much the same no matter where they are produced, and all grain or oil of a particular grade trades for the same price no matter what its country of origin or how much it costs to produce. Changes in exchange rates will not affect the relative prices of foreign and domestic grain and should, therefore, have little effect on the volumes of commodity trade flows.[1]

This suggests, then, that the right concept of "total" trade for our purposes ought to be total trade likely to be affected by exchange rate changes. The degree to which trade in different sectors will be affected by exchange rate changes will vary across a broad spectrum, with true commodities at one end and specialized manufactures at the other. As a crude approximation, we might postulate that manufactures are generally affected by exchange rate changes and that other merchandise and services trade is not much affected. This would lead us to exclude from our concept of "total" trade all trade other than in manufactured goods. Operationally, our definition of "total" trade includes trade in SIC categories 301 through 399.

## REDUCING THE NOISE IN THE TRADE PERFORMANCE MEASURES

The most important exclusions that result from this choice are trade in oil and in agricultural products. These exclusions have a further practical benefit. During the period covered by our analysis, oil prices and the prices of agricultural commodities have fluctuated widely. These fluctuations could distort the trade performance metric. To see how, consider two sectors, $i$, and $j$. Let $x_i$, $x_j$, $m_i$, and $m_j$ denote, respectively, the percentage changes in the values of exports and imports of goods in (non-oil) sectors $i$ and $j$. Further, let $x$ and $m$ (without subscripts) denote the percentage changes in the values of all exports and imports, including oil. Now suppose that sectors $i$ and $j$ have identical trade performance as measured by the metric $G$ as defined in Sec. 3.[2] That is, suppose that:

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[1] This is strictly true only for modest changes in exchange rates. If the value of the local currency appreciates sufficiently to reduce the world price (expressed in local currency terms) to below the marginal cost of lifting oil or producing grain, local producers will go out of business and trade patterns will of course change. Price supports for agricultural products introduce an additional complication. Because U.S. crop support prices, for example, are set in dollars, a strengthening of the dollar will raise the price of U.S. agricultural products relative to similar products produced elsewhere. Consequently, exchange rate changes will change relative prices of agricultural products from different sources and probably trade patterns. A particularly striking example of such changes occurred in the early 1980s. The combination of U.S. support prices and a strong dollar priced U.S. grain out of many international markets. One consequence was a decline in U.S. wheat acreage and a simultaneous rise in French acreage planted in wheat.

[2] The arguments that follow apply equally well to the trade performance metric $F$. The algebra is simpler for metric $G$, however, and we therefore use this metric for our

$$G_i = \frac{x_i}{x} - \frac{m_i}{m} = \frac{x_j}{x} - \frac{m_j}{m} = G_j \ . \tag{D.1}$$

Now consider an alternative case in which all trade flows are the same as in the first case but in which oil prices have risen sharply. These higher oil prices will obviously result in a higher value of $m$, the percentage increase in the value of "all" imports. The values of $x_i$, $x_j$, $m_i$, and $m_j$ will be the same as in the first case. The value of $x$ may also rise a bit (although by nowhere near the amount that $m$ rises) because the United States does export a small amount of oil. Let $a$ and $b$ denote the multiplicative factors by which $x$ and $m$ rise, respectively, compared to the first case. Thus, $x'$ and $m'$, the percentage increases in all exports and imports in the second, or oil-price, case will be related to $x$ and $m$ in the previous case in this way:

$$x' = ax \text{ and } m' = bm \ .$$

Since real trade flows are the same in the two cases, it might be reasonable to expect that the metrics of trade performance for sectors $i$ and $j$ would be the same in the two cases. Calculating these metrics for the second case, though, we see that:

$$G_i' = \frac{x_i}{ax} - \frac{m_i}{bm} \tag{D.2}$$

$$= \left(\frac{x_i}{x} - \frac{m_i}{m}\right) - \left(1 - \frac{1}{a}\right)\frac{x_i}{x} + \left(1 - \frac{1}{b}\right)\frac{m_i}{m} \tag{D.3}$$

$$= G_i - \left(1 - \frac{1}{a}\right)\frac{x_i}{x} + \left(1 - \frac{1}{b}\right)\frac{m_i}{m} \ . \tag{D.4}$$

Similarly,

$$G_j' = G_j - \left(1 - \frac{1}{a}\right)\frac{x_j}{x} + \left(1 - \frac{1}{b}\right)\frac{m_j}{m} \ . \tag{D.5}$$

$G_i'$ and $G_j'$ will be equal only if $x_i = x_j$ and $m_i = m_j$ or if $a = b$. The first condition—that exports in the two sectors increase by the same percentages and that imports do likewise—will not generally hold. The second condition will hold only if the commodity whose price is chang-

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illustration. Since metric $H$ is based on ranks rather than ratios, it is less sensitive to the changes in other sectors, even if those sectors have large dollar values.

ing accounts for roughly equal shares of total imports and total exports. This is obviously not the case with oil.

Equations (D.4) and (D.5) demonstrate that the relationship between the trade performance metrics of any two sectors will in general be distorted by a price change in any third sector. The size of this distortion can be minimized if we restrict our definition of "all" trade to products that:

1. Constitute a small share of total imports or exports (that is, products for which a change in prices will result in only small values of $a$ and $b$),
2. Constitute roughly similar shares of imports and exports (that is, products for which a change in prices will result in roughly equal values of $a$ and $b$), or
3. Will show price changes generally in line with price changes for other traded products (that is, products for which prices will seldom give rise to anything other than small values of $a$ and $b$).

Two classes of commodities that certainly do *not* meet these conditions are oil and agricultural products. We therefore exclude them from our definition of "all" trade. Other commodity-like products will probably not create the same kinds of problems as will oil and agriculture—mostly because these other products account for only small shares of total U.S. trade. The prices of these products do sometimes swing erratically, though, and to be on the safe side, it is probably wise to exclude them also. We cannot totally eliminate the distortions in the trade performance metric that will result from changes in the prices of "third" products. By restricting our definition of "all" trade to manufactures, though, we will minimize these distortions.

## MINIMIZING ERRORS IN THE INPUT-OUTPUT TO SIC CONVERSION

An additional reason for the exclusion of nonmanufactures from the trade performance calculations is related to the requirement that the I-O categories be converted to SIC categories. This conversion was necessary to measure industry trade performance using the SIC-based trade data. In this case, the 79 I-O industries were mapped into the 159 three-digit SIC industries. In most manufacturing industries, this resulted in a one-to-one or one-to-many concordance, where a single defense-competing metric for each I-O classification would be applied to one or more SIC industries.

In some cases, the concordance was not easily accomplished. For example, in some agricultural industries, the concordance between I-O and SIC classifications is complex. In certain service industries represented in the I-O classification system, there are no relevant trade statistics. Since these problems are minimal in the conversion of the manufacturing industries from the I-O to the SIC classification systems, the trade performance figures for manufacturing were more reliable and were used in the trade analysis. The concordance is shown in Table D.1.[3]

## Table D.1

## I-O to SIC Concordance

| I-O Code | I-O Title | SIC Code | SIC Title |
|---|---|---|---|
| 32 | Rubber and miscellaneous plastics | 301 | Tires and tubes |
| 32 | Rubber and miscellaneous plastics | 302 | Footwear, rubber or plastic |
| 32 | Rubber and miscellaneous plastics | 303 | Reclaimed rubber |
| 32 | Rubber and miscellaneous plastics | 304 | Hose and belting |
| 32 | Rubber and miscellaneous plastics | 306 | Plastic/rubber medical supplies |
| 32 | Rubber and miscellaneous plastics | 307 | Miscellaneous plastics products |
| 33 | Leather tanning and finishing | 311 | Tanned and finished leathers |
| 34 | Footwear and other leather | 313 | Leather, cut to shape |
| 34 | Footwear and other leather | 314 | Footwear, leather |
| 34 | Footwear and other leather | 315 | Leather gloves |
| 34 | Footwear and other leather | 316 | Leather luggage |
| 34 | Footwear and other leather | 317 | Handbags of leather |
| 34 | Footwear and other leather | 319 | Miscellaneous leather goods |
| 35 | Glass and glass products | 321 | Flat glass |
| 35 | Glass and glass products | 322 | Glass or glassware |
| 35 | Glass and glass products | 323 | Glass products |
| 36 | Stone and clay products | 324 | Cement |
| 36 | Stone and clay products | 325 | Structural clay products |
| 36 | Stone and clay products | 326 | Ceramic products or china |
| 36 | Stone and clay products | 327 | Concrete/gypsum/plaster products |
| 36 | Stone and clay products | 328 | Cut stone or stone products |
| 36 | Stone and clay products | 329 | Abrasive mineral products |

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[3] Degrees of freedom in the regression analyses are measured by the number of independent observations. These are determined by the number of different I-O industries rather than the resulting number of SIC industries.

## Table D.1—continued

| I-O Code | I-O Title | SIC Code | SIC Title |
|---|---|---|---|
| 37 | Primary iron and steel manufacturing | 331 | Steel mill products |
| 37 | Primary iron and steel manufacturing | 332 | Iron and steel products |
| 38 | Primary nonferrous metals manufacturing | 333 | Refined nonferrous metals |
| 38 | Primary nonferrous metals manufacturing | 335 | Rolled /other nonferrous metal |
| 37 | Primary iron and steel manufacturing | 339 | Primary metal products, nspf |
| 39 | Metal containers | 341 | Drums, cans, or boxes of metal |
| 42 | Other fabricated metal products | 342 | Cutlery and saw blades |
| 40 | Heating, plumbing, and fabricated metal products | 343 | Heating equipment |
| 40 | Heating, plumbing, and fabricated metal products | 344 | Fabricated structural metal products |
| 41 | Screw machine products, stampings | 345 | Fasteners of metal |
| 41 | Screw machine products, stampings | 346 | Metal forgings and stampings |
| 13 | Ordnance and accessories | 348 | Ordnance and accessories |
| 42 | Other fabricated metal products | 349 | Fabricated metal products, nspf |
| 43 | Engines and turbines | 351 | Engines and turbines |
| 44 | Farm and garden machinery | 352 | Farm and garden machinery |
| 45 | Construction and mining machinery | 353 | Construction and oil field machinery |
| 47 | Metalworking machinery | 354 | Metalworking machinery |
| 48 | Special industry machinery | 355 | Special industrial machinery |
| 49 | General industrial machinery | 356 | General industrial machinery |
| 51 | Computers and office machines | 357 | Computers and office machines |
| 52 | Service industry machines | 358 | Refrigerators/service industry machines |
| 50 | Miscellaneous nonelectrical machinery | 359 | Nonelectrical machine parts |
| 53 | Electric industrial machines | 361 | Electric distribution equipment |
| 53 | Electric industrial machines | 362 | Electrical industrial apparatus |
| 54 | Household appliances | 363 | Household appliances |
| 55 | Electric lighting and wiring | 364 | Electric lighting equipment |
| 56 | Radio, TV, and communication equipment | 365 | Radio and TV equipment |
| 56 | Radio, TV, and communication equipment | 366 | Communication equipment, nspf |
| 57 | Electronic components | 367 | Electronic components |
| 58 | Miscellaneous electrical machinery | 369 | Electrical machinery, nspf |
| 59 | Motor vehicles and accessories | 371 | Motor vehicles and parts |
| 60 | Aircraft and parts | 372 | Aircraft and parts |

## Table D.1—continued

| I-O Code | I-O Title | SIC Code | SIC Title |
|---|---|---|---|
| 61 | Other transportation equipment | 373 | Yachts and pleasure boats |
| 61 | Other transportation equipment | 374 | Railroad equipment |
| 61 | Other transportation equipment | 375 | Motorcycles and bicycles |
| 13 | Ordnance and accessories | 376 | Missiles and space vehicles |
| 61 | Other transportation equipment | 379 | Miscellaneous transportation equipment |
| 62 | Scientific and controlling instruments | 382 | Measuring and controlling instruments |
| 63 | Optical and photographic equipment | 383 | Optical instruments |
| 62 | Scientific and controlling instruments | 384 | Surgical and medical instruments |
| 63 | Optical and photographic equipment | 385 | Ophthalmic goods |
| 63 | Optical and photographic equipment | 386 | Photographic equipment |
| 62 | Scientific and controlling instruments | 387 | Watches and clocks |
| 64 | Miscellaneous manufacturing | 391 | Jewelry and silverware |
| 64 | Miscellaneous manufacturing | 393 | Musical instruments |
| 64 | Miscellaneous manufacturing | 394 | Sporting goods and toys |
| 64 | Miscellaneous manufacturing | 395 | Pens, pencils, and artist's materials |
| 64 | Miscellaneous manufacturing | 396 | Costume jewelry |
| 64 | Miscellaneous manufacturing | 399 | Miscellaneous manufactured products |

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