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Miscellanea

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Measuring Advanced Technology Products Trade: A New Approach

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Abstract: Existing procedures used to construct high technology trade statistics do not provide an accurate picture of international trade in these products because of the level of aggregation used in their construction. Many low technology products are included in published trade statistics for high technology industries. In order to provide policymakers with improved information on high technology trade, the U.S. Census Bureau now publishes monthly trade statistics on advanced technology products (ATP). This paper discusses the methodology used to define the Census Bureau ATP measure and contrasts it with the existing procedures.

Key words: High technology trade; trade balance; ATP; DOC3.

1. Introduction

As part of U.S. Census Bureau efforts to provide policymakers and other interested parties with the most complete and accurate information possible, we recently completed a review of the methodology and data used to construct high technology trade statistics. Our findings suggest that existing procedures do not provide an accurate picture of international trade in high or advanced technology products (ATP) because of the level of aggregation used in their construction. For example, a recent International Trade Administration (ITA) publication (1989) shows that the U.S. high technology trade balance fell from a 24 billion U.S. dollars surplus in 1982 to a 2.6 billion deficit in 1986, before rebounding to a 591 million surplus in 1987. Using our new disaggregate, product-based measure of the international

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trade in ATP, we find that although the U.S. trade balance in these products did decline over the 1982–1987 period, the decline is much smaller (about 5 billion) than that reported by ITA (approximately 24 billion).

The ITA statistics are based on the Department of Commerce's DOC3 definition of high technology industries, Davis (1982). Similar definitions are in use throughout the world. The DOC3 definition classifies each product produced in a high technology industry as a high technology product. As a result, many products that would not normally be considered high technology are included in the published statistics, Abbott, McGuckin, Herrick, and Norfolk (1989). Based on this finding and after extensive consultations with scientists, engineers, and policymakers throughout the government and private sector, the U.S. Census Bureau began regular monthly publications of new ATP measures in January 1989. Country specific coverage was initiated one year later in January 1990. This paper discusses the methodology used to define the U.S. Census Bureau ATP measure, contrasts it with existing DOC3 measures, and provides a comparison of the resulting statistics. After discussing alternative approaches to identifying advanced technology products, Section 2 describes the development of the U.S. Census Bureau ATP classification. This classification is based on an examination of the technology embodied in each product. It represents a bottom-up rather than top-down approach building the trade balance statistics from the microdata rather than using the industry-level information as the basis for classification. Appendix B, available on request from the authors, provides a comprehensive list of current ATPs. These data are available on a TSUSA/Schedule B basis for the 1982–1988 period and on a harmonized basis for 1989 and later years.

Section 3 examines annual ATP trade statistics for the 1982–1988 period and compares these with equivalent ones based on the DOC3 measure. Differences between the two measures primarily arise from changes in the balance of trade of items included in the DOC3 measure but excluded by the U.S. Census Bureau ATP measure; i.e., trade in low technology products that are produced in high technology industries. Large differences in high technology trade shares between European countries are reported by Amendola and Perrucci (1990) based on comparisons using traditional definitions like DOC3 and corroborate a principal argument for construction of the ATP measure, that the DOC3 measure of high technology trade is biased because of the level of aggregation used in its construction. They also suggest that at the level of individual products, the U.S. high technology sectors continue to enjoy a strong comparative advantage over their foreign competitors.

Section 4 provides some concluding remarks concerning the definition of high technology trade and the construction of statistics designed to measure it.

2. Defining Advanced Technology Trade – Current Definitions

Most current definitions of high or advanced technologies use indirect measures of the "technology embodied in the product" to determine which industries are high technology. For example, the ITA's DOC3 definition is based on the ratio of research and development expenditures to sales for the industry (Davis 1982) while the Bureau of Labor Statistics (BLS) has experimented with several measures based on the ratio of "scientific and engineering" employees to other employees (Riche, Hecker, and Burger 1983). Unfortunately, several problems exist with the use of indirect measures of embodied technology. First, the indirect measures avoid the issue of defining high technology by pushing it back to the definition of research and development expenditures and scientific and engineering employees without regard for how these factors are defined or how they affect current products.

Second, these indirect approaches must rely on aggregated industry-level data to classify high technology products because such data are not available on a product-line basis. As a result, these indirect methods must assume that all products within an industry are either high technology or low technology. This top-down approach leads to substantial misclassification. Our analysis of the individual products shows that most high technology industries produce a mixture of both high and low technology products. For example, the Office and Computing Machines Industry (SIC 357) is included in almost every definition of high technology even though the products in this industry include: scales, balances, cash registers, calculators, dictation recorders, adding machines, and computers. Clearly, not all of these products would be considered as embodying advanced or leading-edge technologies. Moreover, the proportion of high and low technology products traded may change dramatically over time. For example, in Computers (SIC 357) the proportion of total imports that were high technology increased from 62% in 1982 to 85% in 1987 according to the ATP measure.

A third problem with the indirect approach is that it does not make a distinction between the product and the process used to make the product. Research and development associated with more efficient production processes may not result in better, or more advanced, products. For example, recent developments in petroleum refining have led to great reductions in the amount of "waste" or residual fuels. These new processes require sophisticated control equipment and a larger number of engineers. As a result, the petroleum industry has been included in the BLS definition of high technology. But, is gasoline a high technology product? There is no difference between gasoline refined using the old and new processes. In this case it is the process, not the product, which embodies the high technology.

The Inorganic Chemicals Industry (SIC 281) is perhaps a better illustration of the product-process distinction from the standpoint of the DOC3 definition. This industry is included in the DOC3 definition because it has a relatively high research and development to sales ratio; however, much of the research and development is focused on new production processes. As a result, low technology products such as sodium carbonate (soda ash) are included in the DOC3 high technology trade balance – in 1986 soda ash was the largest U.S. export for this industry accounting for 232 million U.S. dollars in exports.

In an effort to gain better data on the use of high technology production processes, the U.S. Census Bureau has undertaken a survey of manufacturing plants designed to ascertain the nature of the technologies used in the specific industrial establishments. The results of this survey will provide some less aggregated information on the use of high technology processes. If, as the gasoline and inorganic chemicals examples suggest, competition in low technology products is dependent on high technology processes, then for purposes of competitive analysis, the advanced technology processes are important. This aspect of the relationship between production technology and trade is not picked up in either the advanced technology products definition or the

DOC3 measure, which excludes petroleum refining.

In order to allow for the heterogeneity of individual products within an industry and to focus on the nature of the traded product rather than the production process, one must examine international trade at the product level rather than at the industry level. Unfortunately, at such a detailed level, input-based measures such as research and development expenditures are not available, nor are they likely to be available in the near future. As a result, in a process described more fully below, a list of advanced technologies are used to identify individual ATP products.

2.1. The U.S. Census Bureau's advanced technology products definition

The best way to overcome the problems inherent in the DOC3 (and BLS) definition is to conduct an examination of individual products to determine whether they are high technology. The first step in formalizing this process was the development of a list of technological fields to be included under the heading of advanced or high technologies. In creating this list of high technology fields, U.S. Census Bureau analysts consulted a number of different sources including: *Fortune Magazine* (October 13, 1986), CorpTech (1986), and International Trade Administration (1989).

From these sources, ten fields were identified as comprising high technology in today's society: Biotechnology, Life Sciences (Medical Science), Opto-Electronics, Computers and Telecommunications, Electronics, Computer Integrated Manufacturing, Materials Design, Aerospace, Weapons, and Nuclear. Please note that these technological fields *do not* correspond to any existing industry definitions. These fields do, however, represent the technological areas where the rapid development of new concepts and ideas have led to many breakthroughs that could be considered on the leading edge of modern technology. Descriptions of these fields and examples of the specific applications and breakthroughs, which we consider high technology, are provided in Appendix A.

2.2. Application of leading-edge technologies to individual products

The second step in constructing our list of advanced technology products was the examination of individual products that are traded by the United States to determine whether significant amounts of any of the leading-edge technologies were embodied in the product. If a product contained significant amounts of one or more of these technologies, it was considered to be an ATP. If the product did not contain a significant amount of one of these technologies it was considered an "other" product.

Although one would clearly like to make this definition more quantitative by placing a value on the contribution of the advanced technologies to the product, such standards are not practical. For this reason, analysts were instructed to use their knowledge and judgment to determine whether or not a particular product contained significant amounts of these technologies.

Clearly, this method is not perfect. Although most people would agree that advanced technology products are those that embody special knowledge, training, and technology, it is very difficult to establish clear cut rules for classifying individual products as high technology and "other." The U.S. Census Bureau procedure relies on the judgment of individual industry analysts to evaluate and determine whether a product is high technology or not. This means that another set of analysts, working with the same data, may identify a somewhat different list of ATPs.

Although these problems of classification are difficult, they should not be overdrawn. Decisions similar to those made in developing the list of ATPs are regularly made in the classification of economic activity and other related U.S. Census Bureau activities. Moreover, one should be reminded that the industry definitions used by others to construct their measures of high technology trade are themselves based on U.S. Census Bureau decisions as to the assignment of individual establishments (and products) to particular industry groupings. Without such decisions, one could only work with aggregate data or with the universe of individual establishments. Thus it is natural to apply this same expertise to defining advanced technology directly through the classification of individual products rather than indirectly through research and development expenditures or scientific personnel, both of which clearly have as many definitional problems.

Nonetheless, to minimize the effect of these subjective decisions, the U.S. Census Bureau has adopted several procedures. First, the judgments of the analysts were reviewed by trade experts inside and outside the U.S. Census Bureau. The analysts were pushed to justify the inclusion or exclusion of individual products, and in some cases, revisions were made. Such reviews are carried out on a regular basis so that new products can be incorporated in the list and products, which become data, can be removed from the list. It is important to keep in mind that technologies are not static. New inventions and products continuously replace old products as the leading edge of science and industry continuously advance into new areas. Thus, any list of high technology products cannot be static and must be continuously revised. Second, detailed studies of the differences between the U.S. Census Bureau ATP measure and the DOC3 measure are used as the basis for specific review of products.

Third, data on the level of imports and exports of products included in either the U.S. Census Bureau ATP or the DOC3 definition of high technology are available to users, Abbott (1990). Thus, researchers can examine both measures at a detailed level and conduct sensitivity analysis to determine the effects of including or excluding specific products from either measure.

3. Comparing ATP and DOC3 Measured Trade Balances

Figure 1 contrasts the ATP and the DOC3 measures of the high technology trade balance. (The ATP measure of high technology trade is the upper line in Fig. 1.) One striking feature is that although both measures are very close in 1982, they quickly diverge and by 1985 the difference between the two measures is approximately 20 billion U.S. dollars. From 1982 to 1985 the two measures move very differently. Both show a decline from 1982 to 1983, but the DOC3 measure shows a dramatic decline, approximately 12 billion, while the ATP measure has a decline of only 3 billion. From 1984 to 1985, the ATP measure shows an increase in the trade balance while the DOC3 measure shows continued decline. From 1985 to 1987 both measures show similar movements, although they are at very different levels. Both decline from 1985 to 1986, and then rebound from 1986 to 1987.

To examine the source of the differences between these two measures, it is useful to classify the traded products into three distinct groups: group 1, those products that are included in both the ATP and the DOC3 measure (375 individual products); group 2, those products that are included in the

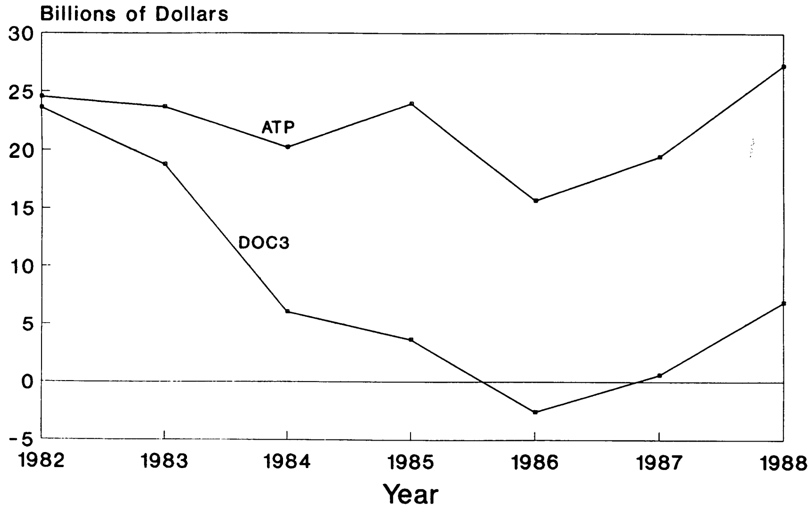

Fig. 1. High technology trade balance. Comparison of ATP and DOC3 measures

ATP measure, but excluded from the DOC3 measure (136 products); and group 3, those products that are included in the DOC3 measure, but excluded from the ATP measure (2,189 products.) It is group 3 products that initially caused concern with the DOC3 measure, and led to development of ATP. This group also provides most of the explanation for the difference between ATP and DOC3 trade statistics.

3.1. Sources of the differences in observed trade balances

Using these three groups of products, the movements over time in either ATP, DOC3, or the difference between the ATP and DOC3 measures can be examined. The time trend of each of these components is shown in Fig. 2. The group 1 products, those common to both the ATP and DOC3 measures, decline from roughly a 23 billion U.S. dollars surplus in 1982 to an 18 billion surplus in 1984, before rebounding to 22 billion in 1985. From 1985 to 1986 there is a dramatic drop in the trade balance of these products to a low of 14 billion, before rising again to a 17 billion surplus in 1987. The group 2 products, those unique to the ATP measure, remain roughly flat at about 2 billion surplus over the period. In contrast, the group 3 products (i.e., those low technology products produced in high technology industries) start off with a slightly positive trade balance in 1982 but plunge to an 18 billion deficit in 1985 and slowly rebound to a 15 billion deficit in 1988. Thus, while movements in the ATP measure are dominated by the group 1 products (common to both), the movements in DOC3 measure are dominated by the group 3 products (which are unique to it, and were found to be low technology products by U.S. Census Bureau analysts.)

It is also this group 3 component that explains the differences (both in absolute magnitude and movements over time) between the ATP and DOC3 measured high technology trade balances. This means that the trade balance of low technology products (according to U.S. Census Bureau analysts) in high technology industries (according to ITA) is the primary difference in the two high technology measures, validating the initial concern about using aggregate industry-based measures. More impor-

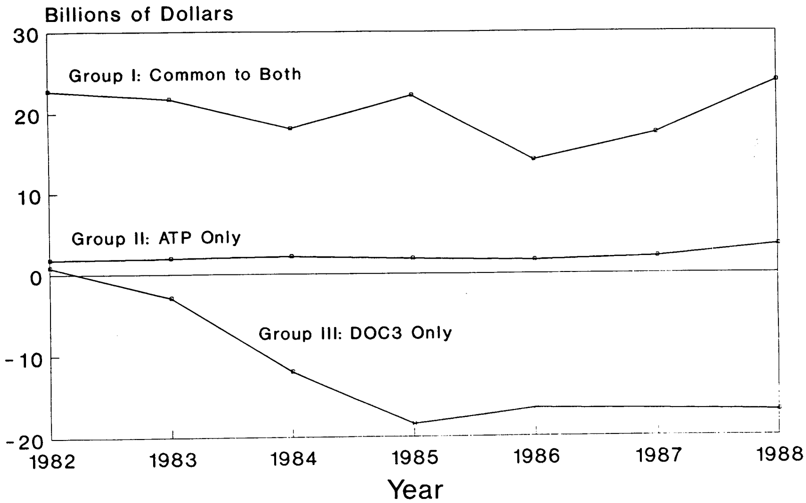

Fig. 2. Contrasting ATP and DOC3 measures. Sources of differences

tant, the differences between the movements and levels of the group 1 and group 3 products provide prima facia evidence that the distinction made by the U.S. Census Bureau analysts between high and low technology products actually reflects real differences in the products. If all of the products manufactured in high technology industries were, in fact, identical (as implicitly assumed in the DOC3 definition) then one would expect the trade patterns of group 1 and group 3 products to be very similar, which clearly, they are not.

The extent of misclassification produced by using the top-down approach varies across both industries and technologies. While we do not report on this aspect in great detail here, Abbott et al. (1989) and Abbott (1991) show that substantial amounts of low technology products are exported by five high technology industries: Communications and Electronic Components, Drugs and Medicines, Professional and Scientific Instruments, and Plastic and Resins. However, the more substantial differences between the top-down and bottom-up approach show up in differences in high technology imports in Communications and Electronic Components and Professional and Scientific Instruments. By far the largest net effect (nearly 17 billion U.S. dollars in 1988) is in the Communications and Electronic Components industry that shows a 20 billion deficit using the aggregate approach and only a 3 billion deficit when low technology products are eliminated.

4. Summary

This paper focuses attention on the question of what is meant by high or advanced technology goods. Do we mean goods produced in research and development intensive industries as is the basis for most existing definitions of high technology trade? Do we mean goods that embody new or leading-edge technology as is done in the construction of ATP? A third possibility could be goods that were produced using complicated or advanced technology processes. As we have seen, these different approaches provide different measures. Most important, having arrived at a definition of high technology, the implementation of that definition is extremely important to the measure of trade in high technology goods. In constructing the ATP measure of international trade, the U.S. Census Bureau focuses on the technology embodied in the individual products and uses analysts familiar with the products to classify them as high technology or "other." Until now, policymakers have had to rely on aggregate industry statistics. This limits the range of policy options that could be evaluated. The U.S. Census Bureau's new ATP measure, and its underlying product level data, provides a wealth of detailed information about international competition at the product level. It is now being produced on the basis of the harmonized Standard Industrial Classification (SIC) system. This level of detail should permit the development, implementation, and review of much more narrowly-aimed policy actions than was possible with more aggregate measures.

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APPENDIX A

1. Advanced or High Technology Fields

The U.S. Census Bureau list of fields involving advanced or high technology is Biotechnology, Life Sciences (Medical), Opto-Electronics, Computer and Telecommunications, Electronics, Computer Integrated Manufacturing, Materials Design, Aerospace, Weapons, and Nuclear Technology. Within each of these fields, large numbers of products, processes, and breakthroughs can be considered to be "on the leading-edge" of their field. Note also, that there is a great deal of overlap across these fields, as breakthroughs in one area typically have applications in other fields. More specific details including a list of products included and excluded from each technology field appear in Appendices B and C, available on request. Descriptions of each field follow.

2. Biotechnology

Biotechnology covers recent developments in recombinant deoxyribonucleic acid (DNA) research and genetic engineering. It is a new field, based on discoveries in the 1950s, and has only recently been applied to the production of goods. The most obvious examples of biotechnology products are drugs, enzymes, and other therapeutic items. The field also has yielded benefits in agricultural production. New genes have been developed, which increase the immunity of plants to diseases, and increase the plants' resistance to various herbicides. New food products are being developed with this technology. In addition, new applications of microorganisms for the production of drugs and other complex molecules hold promise for both new products and processes.

3. Life Sciences (Medical Science)

This field encompasses the application of scientific advances to medical sciences. Recent advances such as nuclear resonance imaging, echocardio-graphs, and total-patient monitoring systems are examples of products developed from recent technological advances in the field. Recent increase in the strength of materials and reductions in their weight has led to improved internally implemented fixation devices and prostheses. Novel chemistry coupled with new production techniques for the manufacture of drugs have lead to many new products for the control or eradication of diseases. There is considerable overlap between products containing life sciences and biotechnology technologies.

4. Opto-Electronics

Opto-electronics is generally defined as the expanded development and application of the laser. However, recent advances in the field also include photoelectric cells and diodes, photographic and other imaging equipment, and fiber-optic cables. Many of the products incorporating opto-electronics technology have military application, and have trade restrictions placed on them. There is considerable overlap between products in this field and those containing advanced telecommunications and materials design technologies.

5. Computer and Telecommunications

This area is intended to cover technological advances affecting both computer and telecommunications hardware products. The distinction between computer and telecommunications products is becoming more difficult to make and has resulted in these areas being combined. The primary advances in this field are on developing hardware that can more quickly process information.

The area of computer products includes new designs that expand the field of applications, the development of increased data storage capacity, and the development of smaller, more efficient peripherals. Important breakthroughs are expected in the areas of artificial intelligence and parallel processing, and new developments in opto-electronics may lead to dramatic gains in computer processing by allowing computers to operate by using photons rather than electrons.

In the area of telecommunications, hardware has been developed that can simultaneously transmit audio and video signals.

In addition, advances in digital signal processing are being incorporated in improved signals switching systems. Breakthroughs in materials design technology have made many of these new products possible.

6. Electronics

The miniaturization of electronic components is the most important recent technological advance in the field of electronics. Extensive development occurring in the design of integrated circuits has improved their performance and capacity, and at the same time, reduced the size of the circuits. Although most discussions focus on integrated circuits, the field has also made significant strides in the design of discrete semiconductors such as transistors and diodes, as well as new developments in surface mounting of electronic components such as capacitors and resistors. Again, there is considerable overlap with computer and telecommunications technology.

7. Computer Integrated Manufacturing

This field includes developments in robotics and numerically-controlled (NC) machine tools. These products have had a significant effect on industrial automation. Robots and NC machine tools perform increasingly sophisticated operations through developments in sensory and visual capabilities of machines. With these breakthroughs the manufacturing processes have increased in flexibility and require less human intervention to operate and maintain production machinery. Robots and NC machine tools are also used in sterile work environments. Many of the new automation technologies are made possible because of breakthroughs in the application and development of faster and smaller computers. So again, there is some overlap in the classification of these technologies.

8. Materials Design

Materials design includes the newest methods of production for products that already exist in the market as well as the development of new products. Recent examples of the technological advancements include high temperature superconductors, advanced polymers that expand the areas of plastic use, and new ultra clear glass that allows fiber optic cable to be used for long distance communication. The materials in this category often facilitate the development and application of other advanced technologies. For example, advances in preparation and design of ultrathin films make possible smaller and faster computer components, and advanced polymers strengthened with carbon fibers are used in the latest weapons, aircraft, and products of nuclear technology.

9. Aerospace

Technological developments in this field include advances that allow planes to fly farther, faster, and higher, to use less fuel, and to have quieter engines. Many of the advances have been adapted to military applications, such as vertical takeoff aircraft and aircraft that require shorter distances for takeoff and landing. Also covered by this area, are aircraft and rocket propulsion systems developed to provide greater efficiency and power. Many of these developments are the result of breakthroughs in other fields, particularly the materials design technologies.

10. Weapons

This field covers all advanced methods used for the development, guidance, and control of weapons intended for national or personal protection and deterrence. Many of the developments in this area are the result of breakthroughs in computers and telecommunication as well as aerospace technologies. Advanced detection of hostile forces and their nature are also included in the field. Products that extend the use of such weapons to unique situations, such as resistance to high temperatures, and high strength are also included. Here there is considerable overlap with materials design technology. Much of the advanced work in this field is secret, and not directly known outside of the Department of Defense.

11. Nuclear Technology

This field covers developments in nuclear power production and primary nuclear reactors. It includes newly designed reactor components that improve the safety and efficiency of nuclear power plants. It also includes developments in the creation and packaging of nuclear fuel, the application of atomic physics to medical, and other areas of science.