The **Manufacturing Innovation** Series

U.S. MANUFACTURING INNOVATION AT RISK

A Study by Joel Popkin and Kathryn Kobe

February 2006

Council of Manufacturing Associations

THE MANUFACTURING INSTITUTE

MANUFACTURING MAKES AMERICA STRONG

Prepared by Joel Popkin and Company for the Council of Manufacturing Associations
and The Manufacturing Institute

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II. Acknowledgements

The Manufacturing Institute and the NAM Council of Manufacturing Associations want to thank the many individuals and organizations that made this report possible.

We want to thank the author, Joel Popkin for his insightful research and writing of this report. Too few economists have a good grasp of manufacturing and its role in the U.S. economy. Joel Popkin is one of those who not only understands manufacturing but knows how to analyze the data that presents the most accurate and relevant picture of our industry. As a former staff member of the President's Council of Economic Advisers, he and his colleagues, especially Kathryn Kobe, have presented policymakers with a thoughtful look into the future of manufacturing.

We are also grateful to the associations — all members of the NAM Council of Manufacturing Associations — that saw the importance of developing this report and provided the financial support to make it happen. Special thanks to the two associations that spearheaded the effort for this report, AMT – The Association for Manufacturing Technology and the Wood Machinery Manufacturers of America. We also thank:

Air-Conditioning & Refrigeration Institute
The Aluminum Association
American Bearing Manufacturers Association
American Fiber Manufacturers Association
American Petroleum Institute
AMT – The Association for Manufacturing Technology
Association of Home Appliance Manufacturers
Association of Independent Corrugated Converters
Copper & Brass Fabricators Council
Copper Development Association, Inc.
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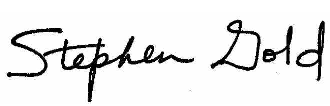
International Sign Association
International Sleep Products Association
IPC – Association Connecting Electronics Industries
Manufacturing Jewelers & Suppliers of America
Metal Treating Institute
Metals Service Center Institute
Motor and Equipment Manufacturers Association
National Marine Manufacturers Association
Paperboard Packaging Council
Plumbing Manufacturers Institute
Precision Metalforming Association
Salt Institute
Wood Machinery Manufacturers of America

We would also like to thank Jerry Jasinowski, president of The Manufacturing Institute, for his interest and support of this research as well as his many comments and good suggestions. Thanks also to David Huether, the NAM's chief economist, who made many invaluable recommendations along the way and to Irina Stepanova for her cover design. We appreciate Noah Cohrssen's help in managing many aspects of the report and Laura Narvaiz for her help in promoting the report widely among the media.



Stephen Gold
Vice President & Executive Director
Council of Manufacturing Associations

I. Foreword

This is the second time we have turned to Joel Popkin and his colleagues for a look at current trends in manufacturing. The last report he authored, *Securing America's Future: The Case for a Strong Manufacturing Bas*e, was written at a time when manufacturing was in the throes of the most severe recession in decades. Much of the rest of the economy was untouched by the economic winds that buffeted manufacturing from 2000 to 2003; it was clear that policymakers needed to know what had happened in this key sector of the economy. That report was well received on Capitol Hill, with the Administration and among manufacturers.

Now the recession has faded, manufacturing output and profits are up, and many manufacturing companies are growing, while others are still struggling. U.S. manufacturing has become a productivity powerhouse, surging 24 percent since the last recession. That's 70 percent faster than the average productivity growth following the last five recessions.

Yet since the last report, the environment for American manufacturing has changed dramatically. Those record high productivity gains in manufacturing have helped make us more competitive, but they have also meant that few of the 3 million jobs lost during the recession have been restored. The expansion of global markets has increased both product and labor competition, while significantly opening up markets for American products. The application of technology and lean manufacturing means that manufacturing output can increase while space requirements, labor demand and costs all decline. U.S. manufacturing has become a productivity and innovation powerhouse, improving competitiveness and driving growth.

In his January 2006 State of the Union address, President Bush recognized that federal policies need to change to ensure that U.S. manufacturing continues to lead in innovation and competitiveness going forward. His recommendations to make the U.S. economy more competitive are in line with what many manufacturers have advocated for many years. When he said that, "our greatest advantage in the world has always been our educated, hard-working, ambitious people — and we are going to keep that edge," he was reflecting one of the strongest messages from today's manufacturing leaders. The Administration's American Competitiveness Initiative includes important pro-manufacturing steps such as greater federal support for basic research in the physical sciences, a permanent R&D tax credit, renewed support for math and science education and reform of immigration.

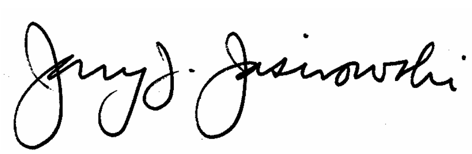
This report was developed well before the State of the Union address because of the dramatic changes that have taken place in the manufacturing environment since the previous report by Dr. Popkin in 2003. It dovetails with the American Competitiveness Initiative, however, as Dr. Popkin has analyzed the underlying trends that are shaping our industry and, in turn, presenting us with the challenges of the future. This report will give any reader a clear understanding about the urgency of moving forward with a bipartisan competitiveness agenda.

It is often said that manufacturing = productivity = technology and innovation. Nearly 60 percent of all private sector R&D is conducted by manufacturers. Manufacturers invent most of the new technologies used in their industry and, through the spillover effect, in services industries as well. It is this flood of new ideas that creates the productivity that in turn differentiates manufacturing from other sectors of the economy. Trends in R&D are important bellwethers for manufacturing, the productivity it generates, our ability to compete globally and the capacity to maintain strong growth.

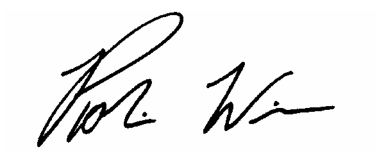
This R&D measure of manufacturing is one of the best indicators of what is to come. Dr. Popkin gives a sobering analysis of the near-term future and points to five warning signs:

- Manufacturing output since the recession significantly lags recoveries of the past 50 years;
- Total plant and equipment investment is lagging, so little new capacity is being built;
- The U.S. share of global manufacturing trade has shrunk from 13 percent to 10 percent, with a marked drop off in machinery, equipment and advanced-technology products;
- There is a growing shortage of skilled workers such as engineers, scientists and technical workers who make up the backbone of the innovation process; and
- The U.S. pre-eminence in R&D is sure to be challenged as growth in R&D has averaged only about one percent a year in real terms.

Who should read this report? Any American who cares about the nation's future well-being. But public officials should especially understand the implications of inaction on policies that will promote, instead of hinder, manufacturing productivity, growth and innovation. President Bush correctly said in his State of the Union address that "we will compete and excel in the global economy." Dr. Popkin presents a convincing argument for action now.



Jerry Jasinowski
President, The Manufacturing Institute



Robin Wiener
Chair, Council of Manufacturing Associations
and
President, Institute of Scrap Recycling Industries

Strong Manufacturing Base —
Crucial to U.S. Leadership in R&D and Innovation

III. Executive Summary

- America's manufacturing innovation process is vital to promoting economic growth, productivity gains and increased living standards. The most important components of this productivity-enhancing process include investments in worker education and training, investments in capital equipment and R&D and its "spillovers" — unintended benefits to other producers and society in general. A strong and vibrant domestic manufacturing base promotes those investments and keeps the innovation process functioning.

- Long-term U.S. economic growth and competitiveness in the global marketplace are at risk if recent trends in domestic manufacturing — and the innovation process it spawns — continue. There are five clear warning signs:
    - Manufacturing **output** since the last recession lags that of earlier economic recoveries — its 15 percent growth since the end of the recession is only half the pace averaged in recoveries of the past half-century.
    - Manufacturing **capacity** remains underutilized, slowing investment in new plants and equipment, an important avenue to introduce new, improved and lower-cost technologies. Since the end of the recession, total plant and equipment investment has risen at half the pace averaged in recoveries of the past half century. Manufacturing capacity has grown at less than one percent annually during this expansion (compared with five percent in the 1990s), reflecting a lack of investment in new facilities.
    - The U.S. share of **global trade** in manufactures has shrunk, falling from 13 percent in the 1990s to 10 percent in 2004. The U.S. share of global trade in some of the highest value-added export industries such as machinery and equipment is falling. Furthermore, the United States now runs a trade deficit in Advanced Technology Products, goods produced in the industries expected to lead U.S. exports in the 21st century.
    - The U.S. manufacturing workforce is highly productive; yet, the perception that manufacturing employment is unstable and lacks job opportunities discourages new workers from pursuing career paths in manufacturing. Manufacturing continues to pay better than many other industries, and it employs 25 percent of scientists and related technicians and 40% of engineers and engineering technicians — critical skill groups for the R&D process — yet the sector is experiencing a growing **shortage of skilled workers.**
    - America's long-standing **leadership in R&D** will be challenged. While the United States continues to spend more than any other country on R&D investment, U.S. growth in R&D has averaged only about one percent per

year in real terms since 2000. And the United States is not keeping up with other countries in insuring a supply of scientific personnel: the portion of doctoral degrees awarded to citizens and permanent residents in the United States in science and engineering is falling, while the combined number of science and engineering graduates in China and India (1 million) now dwarfs those in America (70,000).

- The United States invested more than $290 billion in R&D in 2003, or 40 percent of all R&D spending in the industrial world; the domestic R&D activities of manufacturers accounting for 42 percent of that total. But the United States cannot become complacent about this leadership position. The rapid growth in overseas manufacturing is creating new global centers with the critical mass necessary to build their own innovation machines. Meanwhile, the challenges faced by America's manufacturing base threaten to reduce the critical mass necessary for our own innovation process to work. It diminishes the size of the economic benefit flowing through the sector's high number of linkages that stimulate the rest of the economy. A slower pace of manufacturing production will lead to a weakening in R&D investment and a lack of skilled R&D workers will threaten the pace of innovation in the United States.

- Gains in manufacturing productivity are key to overall U.S. productivity growth. If the innovation process goes offshore and the various wealth-enhancing aspects of that process are lost, a decline in U.S. long-term economic growth rate is all but assured. So the report closes with recommendations for economic policy changes to ensure a critical mass of production and a viable innovation process in this country. Among these policy changes:
    - Emphasize accelerating production in the United States, and in particular encourage investments that enhance productivity, such as R&D investments, capital investments, and investments in education and worker training, encourage and nurture math and science education and talent.
    - Focus on elimination of those workforce, investment and policy obstacles to domestic production and competitiveness that would provide the greatest economic return.
    - Increase federal spending on basic R&D and support of such R&D in U.S. colleges and universities.
    - Encourage innovation clusters to increase spillovers, increase the productivity of R&D spending and spur hands-on development activities.
    - Encourage improvement in the speed and efficiency of the transportation and communication infrastructures of the United States.
    - Improve tax and intellectual property infrastructure needed to leverage investment in R&D.

IV. Introduction

This report complements and updates the 2003 publication, *Securing America's Future: The Case for a Strong Manufacturing Base*. It is prompted by the clear need to examine whether the threats to the U.S. manufacturing base identified in our first report have heightened since its publication.

The current expansion of the U.S. economy is four years old. During this period manufacturing production has risen 15 percent, a little more than 3 percent per year.[1] That is the slowest pace of any of the expansions that have lasted this long during the past 45 years. On average, those previous expansions showed a 30 percent increase in manufacturing this far (49 months) into the business cycle.[2] One reason for the slower rate of growth is that the 1991 recession did not result in as deep a decline in GDP as some of the earlier recessions. But the slower rate of growth for the United States and its trading partners during the early part of the expansion was undoubtedly influenced by the increased uncertainty that followed the events of September 11, 2001.

It was shown in the previous report that manufacturing activity has widespread consequences for the health of the U.S. economy. The most important consequence is manufacturing's impact (through its large multiplier effect on output growth) on investment growth, and on research and development spending, for which it is the major source of funding. Manufacturing's high-capital intensity translates into more plant and equipment spending than in other sectors. The results of manufacturing's R&D can be an endlessly renewable resource that improves the productivity of capital and thus adds to labor productivity. Those results improve the production process and add to the choices

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[1] The peak and trough months used as end points for measurements in this paper are determined by the National Bureau of Economic Research's Business Cycle Dating Committee. It identifies peak and trough months based on a few selected measures of economic activity for the whole economy; thus, manufacturing's experience may not match these dates. That Committee has determined that the peak of the last expansion, and thus the start of the most current recession, was in March 2001 and the trough was in November 2001. That trough marks the start of the current expansion. However, the peak in manufacturing activity was certainly earlier than March 2001 and its trough later.

[2] That is, the increase in the Federal Reserve Board's Industrial Production Index for manufacturing from December 2001 through December 2005. This is based on manufacturing output as defined by the North American Industrial Classification System (NAICS) back through 1975 and manufacturing output as defined by the Standard Industrial Classification System (SIC) for the 1960s expansion.

of goods and services consumers can enjoy. Productivity gains keep those goods and services affordable and they provide the foundation for increases in real wages. Such increases have been the driving force in the advance in the U.S. standard of living since the early days of our industrialization.

All these linkages were explored in depth in the previous report and are further fleshed out with new and updated data in this one. That report suggested that successful R&D requires a certain critical mass. Since then, that premise has gained additional prominence. That is because the rapid growth of other global economies is generating considerable R&D activity abroad, some by U.S. companies. The United States is still the world's leader in R&D but, as its share of world manufacturing shrinks, that lead is at risk. As the manufacturing base in other countries gains ground, it begins to drive increases in their R&D, just as it has done here. One consequence is that the U.S. share of world R&D has been shrinking and that trend is unlikely to abate soon. This threatens our competitive edge in world markets and our lead among large industrial countries in real income per capita, a widely used indicator of the standard of living.

This report has nine sections. The following section, Section V, describes the process through which manufacturing raises our standard of living and preserves our competitiveness in world markets. Section VI updates and enlarges on the set of data that depict the current state of manufacturing. Section VII details the benefits from manufacturing that are threatened, particularly R&D, plant and equipment investment, and the quality of labor. Section VIII draws together the conclusions of this report's analysis and Section IX provides a suggested bibliography of further reading on many of the topics explored.

V. The Process by Which Manufacturing Raises the U.S. Standard of Living

The U.S. manufacturing sector should not be taken for granted. It is at the heart of a process that is critical to the health of the United States economy — the process of generating prosperity, *i.e.*, wealth and real income gains. Because this process —

basically an innovation process — is intensely interactive, its maintenance requires a strong, growing manufacturing sector. The innovation process not only drives the introduction of new products but is made more productive by the process itself. Manufacturers estimate that every two to three years over one-third of their revenue is generated from new product sales.[3] Thus, a large percentage of today's manufactured goods will be obsolete within a few years. That makes innovation a necessity to merely maintain the status quo, and constant innovation is the only way to increase prosperity.

It is perhaps easiest to understand this innovation process by tracing through the interactions beginning with an initial component, research and development investment. Basic R&D produces inventions. Spending on applied research and development spawns innovation — the process by which inventions are implemented.[4] But this R&D-driven process does not stop there. It is magnified by "spillovers," channels by which an innovation in one area freely stimulates those in other areas.

Innovations are diffused through the economy in a number of ways. The most obvious direct linkage is through the production of new goods, and quality improvements in existing goods. Successful R&D not only affects the kinds of goods that flow to consumers but also enhances the labor and capital inputs used to produce them. As capital goods are improved in speed, accuracy and quality, they rely on and often lead to new processes to make their utilization more efficient. Reaping the benefits of such improvements in manufacturing processes requires that human capital (labor skills) keep

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[3] "Mastering Innovation Exploiting Ideas for Profitable Growth," Deloitte Research, 2005.

[4] "The Competitiveness of U.S. Research Universities," a recent study by the Washington Advisory Group offers the following definitions of the R&D taxonomy on page iv:

- R&D refers to both the conduct of research and development as well as R&D facilities. R&D is performed for the purpose of "increasing the stock of knowledge, including knowledge about humanity, culture and society."
- Research is systematic study directed toward fuller scientific knowledge or understanding of the subject studied. The federal government categorizes research as either basic or applied according to the nature of the work and the outcomes.
- In basic research, the objective is to gain fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts.
- In applied research, the objective is to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
- Development is the systematic application of knowledge or understanding directed toward the production of materials, devices and systems or methods, including design, development and improvement of prototypes of new processes to meet specific requirements.

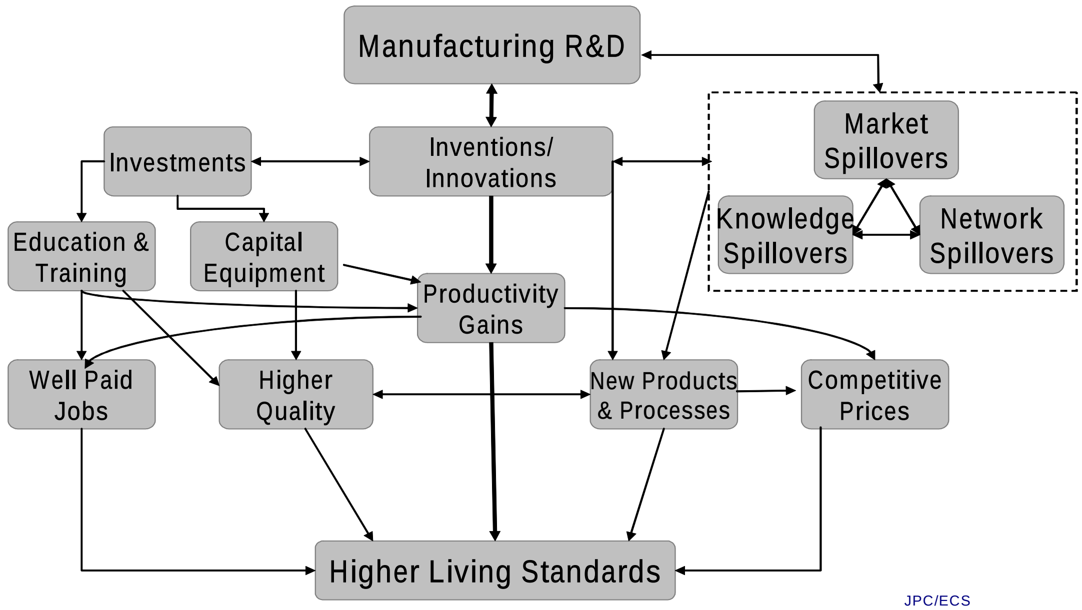
pace. This demand prompts investment in education and training. This process and the investment it promotes leads to productivity gains, the basis for higher living standards.

Large and frequent innovations, the hallmark of U.S. manufacturing, require a certain mass of interconnected activities which, like a snowball rolling downhill, grows in size as it proceeds toward final consumers. The snowball effect requires substantial R&D, enough to be sure of significant successes after writing off failures. The successes must be frequent enough to keep the ball rolling by prompting interactions among the different parties to the process. As size and frequency of innovations rise, spillovers are magnified. The vehicles for the diffusion of new ideas and products along the supply chain are sales transactions, face-to-face discussion of ideas and needs, conferences and meetings of scientific professionals, scientific literature written in a common tongue, etc.

All of those activities are nurtured by geographical proximity. Dr. Maryann Feldman, Professor of Business Economics at the University of Toronto, expressed this in a paper delivered at a National Academy of Sciences conference in January 2005. "Co-location facilitates knowledge spillovers by providing, often at less cost, opportunities for both planned and serendipitous interactions." Thus the process of wealth generation is most efficient when mass and proximity are wedded.

Figure 1: Manufacturing Matters

Its Innovation Process Generates Wealth



What follows is a description of the method by which innovations become an integral part of the economic process and lead to widespread improvements in productivity and our level, or standard, of living. A simplified schematic of the innovation process is shown in Figure 1.

R&D promotes economic prosperity through a multifaceted and complex process:

- The first avenue is through direct benefits to firms from their R&D investments. Those direct benefits, or the need to balance the potential benefits a rival might gain from R&D, are the primary driver of firm-financed R&D.

- The second is through "spillovers" whereby innovations flowing from R&D performed by one organization benefit other organizations without direct compensation for the innovation.

- The third is through the widely discussed multiplier — the effect of one industry's investment on other industries and the U.S. economy as a whole.

- The fourth is the feedback from R&D and its spillovers to improve manufacturing products, processes and distribution networks.

- Together these benefits produce productivity gains that lead to competitive prices and better paying jobs.

In any economy, manufacturing is a major dynamo of R&D spending. Over the past 20 years, manufacturing has performed almost 60 percent of all R&D in the United States. The National Science Foundation estimates total R&D spending performed by private industry in 2003 totaled $204 billion.[5] R&D performed by manufacturing industries totaled $123 billion, or 60 percent of total private R&D and about 42 percent of all R&D performed in the United States.[6] Industry, dominated by manufacturing, also funded about 63 percent of domestic R&D in 2003. Manufacturing is estimated to have

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[5] "Increase in U.S. Industrial R&D Expenditures Reported for 2003 Makes Up for Earlier Decline," by Raymond Wolfe, *Info Brief*, National Science Foundation, December 2005.

[6] As will be explained later in the paper, this somewhat underestimates the R&D connected with the manufacturing sector. Firms classified in wholesale and retail trade perform an additional $20-25 billion of R&D related to their manufacturing establishments.

funded almost 60 percent of business sector R&D. The other funders of domestic R&D are government and nonprofit organizations such as colleges and universities.

The forces of globalization are changing the face of R&D and investment. As manufacturing rapidly expands in other countries, their R&D base will expand as part of that general process. As R&D opportunities expand, U.S. companies will expand the geographic scope of their R&D as well. However, that does not lessen the need to maintain a strong and interactive domestic R&D base. To the contrary, R&D conducted in the United States must keep pace with the economy's growth. National Institute of Standards and Technology economist Gregory Tassey puts the importance of domestic R&D into its broader perspective:

> "Changes in competitive dynamics are altering the reward/risk ratio for R&D investments within and between technology life cycles. As life cycles compress, R&D at the company level no longer can exist in isolation of a supporting network. Corporations increasingly require access to R&D conducted by other firms in their supply chains and to the broader technology infrastructure provided by a national innovation system. If domestic R&D resources are not available, U.S. companies do not hesitate to form research partnerships with foreign companies, outsource R&D overseas, or directly invest in foreign research facilities. These research relationships often lead to follow-on foreign manufacturing relationships. Thus, the maintenance of an effective domestic R&D network is essential for attracting domestic and foreign R&D funds and subsequent manufacturing, which increases domestic value added and hence economic growth."[7]

R&D spillovers are an important factor in the benefits from the innovation process. Spillovers come about when parties derive benefits from the R&D without having to fully compensate the company conducting the research. Spillovers are often characterized in one of three ways, but these pathways often interact and increase their combined effect.[8] One way is through "market spillovers," in which the marketing of a new product creates benefits to market participants other than the innovating firm. Often

[7] "R&D and Long-Term Competitiveness: Manufacturing's Central Role in a Knowledge-Based Economy," by Gregory Tassey, National Institute of Standards and Technology, February 2002, p. 9.

[8] "The Importance of 'Spillovers' in the Policy Mission of the Advanced Technology Program," by Adam B. Jaffe, *Journal of Technology Transfer*, Vol. 23 (2), pp. 11-19.

this is through a new technology that is embodied in products newly developed or improved by R&D. However, because producers cannot capture all of the value of the improvements in the prices they charge for those new goods, cost-free benefits accrue to competitors and customers, or are handed back to suppliers. The improvement in the speed and accuracy of machine tools is one example of such a market spillover. The introduction of numeric controls increased the number and complexity of items for which the use of machine tools was practical. Thus, at least one aircraft maker could make landing-gear bulkheads in two parts rather than 72 parts and reduce the number of fasteners used by more than 90 percent, which increased its productivity and cut its costs.[9]

A second kind of spillover is termed a "knowledge spillover." This is the transmission of knowledge from an R&D activity that can be used by other economic agents in a virtually cost-free manner. For example, academic papers and the information filed with patents provide the readers with information about the process or product being discussed. This cross-pollination of knowledge can spread ideas from one institution to another and from one industry to another with permutations of the ideas taking place at every step. The number of times that one patent is cited by other patents is one way that researchers trace knowledge spillovers.

A third kind is a "network spillover." It occurs when R&D benefits are enhanced in value by the development of a related set of technologies. Thus, extra benefits may accrue to an innovation if related technological innovations also take place. The Internet is an example of a technology that has enhanced the value of communications equipment. The existence of a communications modem allows greater benefits to be derived from computers, and the more people with whom one can communicate on a computer network the greater those benefits.

As mentioned earlier, the spillover effects are magnified — through sales transactions and knowledge transfers — if the parties are more interdependent and closer

[9] "Producing Prosperity — Manufacturing Technology's Unmeasured Role in Economic Expansion," The Association for Manufacturing Technology, September 2000, pp. 13-14.

in their geographic proximity. A paper by Kansas City Federal Reserve Bank economist Michael Orlando discusses the importance of technological and geographical proximity to the spillover process in manufacturing. He finds that spillovers within a manufacturer's own very narrow sector tend to be much less inhibited by distance than are those from outside that narrow sector. In contrast, the impact from spillovers originating outside the manufacturer's narrow sector tends to decrease rapidly with distance.[10] Perhaps this reflects the different paths taken to diffuse the ideas. Firms are more likely to benefit from spillovers when R&D takes place geographically near them than they are if it occurs on the other side of the world, especially with regard to the benefits from more generalized R&D.

A recent study on pharmaceutical R&D finds that spillovers are more noticeable in the local geographic area surrounding where the research has taken place.[11] This appears to be especially true of spillovers from public institutions.[12] Since the federal government and academic institutions perform more than a quarter of R&D, geographic R&D centers with public and private institutions in close proximity can have significant spillover benefits. A recent report by the President's Council of Advisors on Science and Technology (PCAST) found "[l]ocations that possess both strong R&D centers and manufacturing capabilities have a competitive edge. Indeed, several major manufacturers told the PCAST panel that they decided to locate new plants in the United States, despite cost benefits of offshore manufacturing, due to the proximity of leading university R&D capabilities."[13]

One example of a company with a renewed interest in proximity is Honda. Always an innovator, it has renewed its focus on bringing R&D and production

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[10] "Measuring spillovers from industrial R&D: On the importance of geographic and technological proximity," by Michael J. Orlando, *The RAND Journal of Economics*, 35(4), Winter 2004.

[11] "Does Locale Affect R&D Productivity? The Case of Pharmaceuticals," by Margaret Kyle, *Federal Reserve Bank of San Francisco Economic Letter*, November 2004.

[12] The author hypothesizes that this result may be for one of two reasons. First, published research by a competitor may signal a firm that they are too far behind in a certain area and cause that firm to withdraw its efforts from that area. Second, the author speculates that spillovers may require collaboration between researchers and that is less likely to happen between competitors.

[13] *Sustaining the Nation's Innovation Ecosystems*, Report of the President's Council of Advisors on Science and Technology, January 2004.

operations closer together. In a recent interview, Motoatsu Shiraishi, the head of Honda's R&D unit, explained, "[f]or example, when hybrid and fuel-cell cars become more common, it won't be enough to come up with a better product at the research level. We have to make it commercially viable when it's mass produced." Another advantage to the company is that R&D from dissimilar programs can be incorporated on the factory floor into a range of products. In that way Honda's technological know-how from R&D on robots and aircraft have been used to enhance the innovations incorporated into its automobiles. [14]

There are several examples of the benefits of geographic proximity in the United States. Innovators cluster in places like Silicon Valley, Research Triangle and Route 128 in Massachusetts, in part, to obtain spillovers from each other and often to obtain spillovers from academic research that is taking place nearby. The Regional Innovation project of the Council on Competitiveness studied which aspects of such clusters tended to result in increased standards of living of the inhabitants. Among its findings were: 1) "When members of a cluster are located in close proximity, they can capture synergies that increase productivity, innovative capacity and new business formation"; 2) "Commercialization of basic research is a difficult but important ingredient for generating entrepreneurship. Some regions have high levels of R&D investments and numerous specialized research centers, but still lag in terms of innovation output because knowledge is not effectively or rapidly transferred to companies"; and 3) "Above average economic performance measures are not enough to ensure regional prosperity. Maintaining, much less increasing, a region's standard of living requires the steady growth of productivity, which in turn requires innovation."[15]

While close geographic proximity seems to increase spillovers, knowledge transfers take place across geographic distance as well but the pathways may be different. Economist Lee Branstetter of the Columbia Business School has studied spillover

[14] "Honda on R&D To Keep Creative Edge," *The New York Times*, April 3, 2005.

[15] "Clusters of Innovation: Regional Foundations of U.S. Competitiveness," by Michael E. Porter, Council on Competitiveness, 2001, pp. x-xv.

impacts from Foreign Direct Investment (FDI) of Japanese firms in the United States. He found FDI is a channel for knowledge transfers between both parties to the investment. Furthermore, the spillovers to the Japanese investing firm increase when the American investment is in R&D or product development facilities. The flow from the Japanese firm to the American affiliate tends to be strongest through the new "greenfield" establishments where the investing firm is embedding superior technology and/or management practices into those facilities.[16]

The direct output of R&D consists, in concept, of the value of the new products, processes, etc. that result from it. However, that value is generally inferred by spending on the inputs used to conduct it. Obviously, the path from spending on inputs to the value of the outputs can vary considerably based on a wide array of factors and can be difficult to track since spillovers can produce value for participants other than the company spending the money. But, spillovers do help determine how far each dollar of spending can be stretched to create valuable outputs and are important determinants of the "productivity" of R&D spending. This suggests that R&D output can be increased without more spending if spillovers become more pervasive.

Spillovers are not the only reason for maintaining a dynamic domestic R&D base. In a recent article on innovation Michael Orlando and Michael Verba identified two reasons for there to be higher rates of innovation in more densely populated geographic areas, such as large metropolitan areas.[17] The first is the increased possibility for knowledge spillovers in areas where people have a greater opportunity to learn from one another. The second reason is what the authors term "thick markets" for the inputs to innovation. Their argument is that more populous places can support markets for the very specialized personnel and equipment that are needed for R&D, making them a more cost effective place for innovators to work. The authors make the further point that this is

[16] "Is Foreign Direct Investment a Channel of Knowledge Spillovers? Evidence from Japan's FDI in the United States," by Lee Branstetter, working paper, June 2005.

[17] "Do Only Big Cities Innovate? Technological Maturity and the Location of Innovation," by Michael Orlando and Michael Verba, *Economic Review*, Federal Reserve Bank of Kansas City, Volume 90, No. 2, 2005.

especially needed for new innovations because such research may take unexpected turns requiring the acquisition of new and different inputs than were previously needed. These thick markets for the inputs to innovative activities also require replenishment and growth of the types of inputs needed for R&D including technology and skilled personnel. Only ongoing funding and growth of R&D will continue to attract those necessary inputs.

While R&D is the starting point for the innovation, recognition also must be given to the importance of plant and equipment investment to the process and to economic growth. Investment in new equipment provides each worker with more and better capital with which to work. This is often called “capital deepening” or an increase in the ratio of capital to labor. Capital deepening accounted for more than half the growth of labor productivity between 1995-2003.[18]

A thorough quantitative investigation of the relationship between manufacturing and economic growth was conducted in the early 1990s for the World Bank by academic economists J. Bradford De Long and Lawrence H. Summers.[19] The study covered the period from 1960 to 1985, and looked at the behavior of a cross section of 61 nations at various stages of development. It confirmed the relationship and identified capital investment in equipment as a key contributor to manufacturing’s importance as a growth generator. These findings have yet to be seriously challenged; the few subsequent research reports only confirm De Long and Summers. A more recent study by Tahir Abdi contains among its conclusions that “doubling M&E [machinery and equipment] investment could raise the TFP [total factor productivity] levels [in Canadian manufacturing firms] by about 20 percent and doubling non-M&E investment [defined as structures] could raise the TFP levels by almost 23 percent.”[20] It is noteworthy that a recent International Monetary Fund paper found that deceleration of capital deepening in

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[18] “Will the U.S. Productivity Resurgence Continue?” by Dale Jorgenson, Mun Ho and Kevin Stiroh, *Current Issues in Economics and Finance*, Federal Reserve Bank of New York, December 2004.

[19] “Equipment Investment and Economic Growth: How Strong Is the Nexus?” by J. Bradford De Long and Lawrence H. Summers, *Brookings Papers on Economic Activity*, October 1992.

[20] “Machinery & Equipment Investment and Growth: Evidence from the Canadian Manufacturing Sector,” by Tahir Abdi, Canadian Department of Finance Working Paper 2004-4.

the Euro area has been identified as the key factor explaining its slower growth in labor productivity during the 1990s when compared with the United States.[21]

Manufacturing firms themselves have been significant investors in capital equipment, in addition to producing a steady stream of improved capital equipment for other industries to use. Over the past 20 years, manufacturing industries have accounted for 20-30 percent of new investment in equipment and 10-17 percent of new nonresidential structures.[22]

VI. Manufacturing's Challenges More Critical Since Last Recession

Manufacturing generates a large share of American prosperity. While no one can determine its ideal size to sustain and grow the critical mass of innovation, the process by which those benefits are produced, described in Section II, clearly requires one.

There are five signs that the process is endangered; perhaps its long-term health is more endangered than in 2003, when the previous report was written. Those signs are: (1) manufacturing output has continued to lag that of earlier economic recoveries; (2) manufacturing capacity remains underutilized so investment in new plant and equipment, particularly greenfield plants, has slowed; (3) the U.S. share of world trade in manufactured goods generally, and capital goods in particular, continues to shrink; (4) the sector's lack of job growth has discouraged new workers from entering the industry, which has serious implications for maintaining a skilled workforce; and (5) U.S. leadership in R&D is being challenged. The remainder of the section describes developments in these five areas.

A._The Measured Recovery of Manufacturing

Manufacturing production is growing. Since the end of the recession, output has increased 15 percent. However, that is only half its average pace during earlier

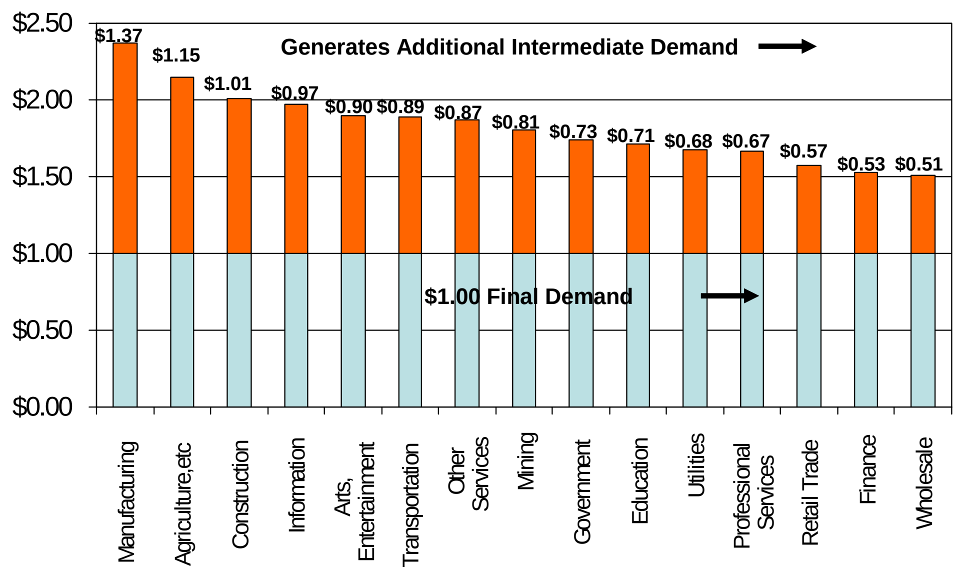
[21] "Why Is Productivity Growth in the Euro Area So Sluggish?" by Marcello M. Esevao, International Monetary Fund Working Paper WP/04/200, International Monetary Fund, October 2004.

[22] Investment in Private Equipment and Software by Industry and Private Fixed Investment in Structures (table), Bureau of Economic Analysis, U.S. Department of Commerce.

expansions over the past 45 years. That means the rest of the U.S. economy has not been receiving the charge from manufacturing typical of earlier economic expansions.

That charge flows from manufacturing's multiple linkages throughout the economy. One measure of that is the multiplier for manufacturing. It is the highest of all the major U.S. industrial sectors. At 2.37 in 2004, its multiplier means that for each dollar of final demand for manufactured goods, $1.37 worth of additional goods and services is needed to support that demand. Those linkages stimulate activity in other parts of the economy. They also provide potential pathways for innovative ideas and processes to expand, both forward and backward, through the supply chain.

Chart 1: Manufacturing's Linkages to the Rest of the Economy
Intermediate Demand Necessary to Produce $1.00 of Final Demand



Source: U.S. Bureau of Economic Analysis, From 2004 Industry-by-Industry Total Requirements

JPC/ECS

In 1997, manufacturing's multiplier was 2.43. That means that each dollar of final manufacturing demand stimulated $1.43 worth of additional economic activity as compared with $1.37 in 2004. That reduction in the sector's output creation may have come about for any number of reasons, including a change in the way production is organized, contractions within the U.S. manufacturing sector, or a relative price change for goods and services.[23] Whatever the reason, the outcome would appear to be a somewhat smaller stimulative impact on the economy for each dollar of final demand output domestic manufacturers produce. The smaller stimulative impact for the goods that are produced here, combined with the large and growing share of manufactured goods that are imported, weakens the domestic linkages through which the innovation process works.

Capital equipment is one of the major groups of final demand products that are produced by manufacturing. Therefore, purchases of equipment are one of the triggers for the impact of the manufacturing multiplier. Every new machine that is produced generates demand back down the line for the materials, parts and services needed to produce that output. Those customer linkages produce lines of communication that transmit more innovation than just that in the product or service being supplied.

Manufacturing has always played a pivotal role in business cycle developments. As a supplier of goods to other sectors, it sees new orders fall by more than the decline in the trade sector's sales because new orders are also reduced to allow wholesale and retail trade inventory adjustments to take place. This adjustment process continues as finished goods producers pass along order reductions and their inventory realignments to their suppliers. The opposite pattern happens during a recovery. Economic expansions lead the wholesale and retail trade sectors to raise orders in anticipation of rising sales. That is the main reason for the wide fluctuations of the manufacturing cycle.

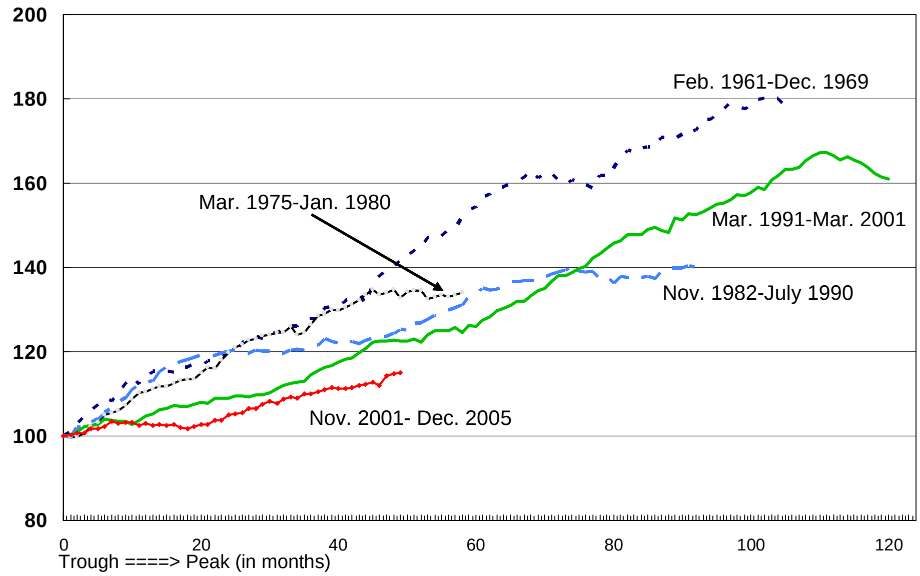
Thus, traditionally manufacturing has led the way in economic expansions, providing important momentum to other sectors. But that has not happened to the same extent in this expansion. Chart 2 compares the growth from trough to peak of the four previous expansions to growth in manufacturing output since the end of the 2001 recession. In the major expansions during the 1960s and 1970s, manufacturing output rose more than 30 percent during the first 49 months of recovery. In the 1980s, growth

[23] Multipliers are based on current dollar relationships and therefore include the effects of changes in quantities and changes in relative prices between one period and the next.

fell a little short of 30 percent in the first 49 months but was up more than 25 percent. Growth during the early part of the 1991 expansion was even slower and it took longer to reach the 30 percent point – over 60 months.[24] The recovery in manufacturing output during the current expansion has been slower than even the 1991 recovery. Output increased by 15 percent in the first 49 months compared with the 23 percent increase registered during the first 49 months of the 1991 expansion.

Chart 2: Manufacturing Production Growth During Recent Periods of Cyclical Expansion

(Cumulative Increase in Manufacturing IP Index From Trough to Peak, Trough = 100)



Source: Derived from data of the Federal Reserve Board, NAICS basis except for 1961 expansion which is SIC basis

ECS/JPC

The slow growth during the early part of the 1991 expansion was not a good predictor of things to come. Innovations and rapid technological change resulted in an acceleration of growth by the mid 1990s. Thus for the 1990s overall, average annual growth in manufacturing was 4.8 percent, a rate not seen since the 1960s. But one dynamic decade does not guarantee a second. The 1960s were followed by average manufacturing growth rates of 3.0 percent in the 1970s, and only 2.5 percent in the

[24] This gave rise to the expansion's characterization as a "jobless recovery".

1980s. So far in the 21st century, manufacturing output has increased only about one percent per year on average.[25]

Growth has been uneven during this expansion. There has been a notable variation between different time periods and different sectors of manufacturing. While that is not an unusual occurrence, there are some worrisome factors in the current statistics. During the first 24 months of this recovery, manufacturing output increased at a pace of less than two percent per year, even registering a decline in output during late 2002 and early 2003. However, starting in mid 2003 the pace of manufacturing output picked up to a rate more typical of the 1990s, increasing five percent between December 2003 and December 2004. Recent performance has not built on that momentum; manufacturing slowed to about a three percent pace during the first three quarters of 2005. This slowdown was evident even before the hurricanes in late August and September. While output growth has shown a post-hurricane spurt, it is unclear if that reflects a stronger growth path or a temporary adjustment.

Output growth has been strongest in the high-technology computer, semiconductor and communications equipment sectors. If those high-technology industries are excluded, industrial production in the traditional manufacturing industries has increased about nine percent since the trough of the recession, about two-thirds the pace those industries had achieved by this time in the 1991 recovery.[26]

B. Total U.S. and Manufacturing Investment Lagging

Total U.S. plant and equipment spending during this recovery is also lagging previous ones. As Chart 3 shows, real investment had grown about 30 percent on average by this point in the recovery cycle during the 1960s, 1970s and 1980s expansions. In the

[25] These decade averages include both recessions and expansions.

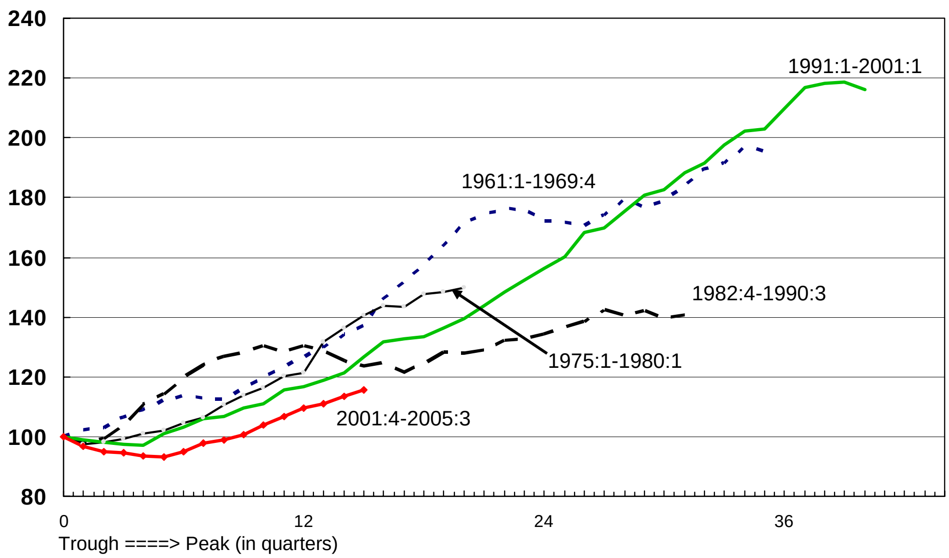
[26] This calculation is done on a Standard Industrial Classification (SIC) basis because the Federal Reserve calculates the manufacturing index excluding computers, semiconductors and communications equipment using an SIC definition for manufacturing. For the most part, the SIC and NAICS definitions for manufacturing vary by one major industry, publishing. In the SIC definitions that was part of the manufacturing sector, under NAICS it is part of the information sector.

1991 recovery, real investment had grown 25 percent by this point. Investment growth in this recovery trails that of earlier recoveries, totaling 15 percent, half the rate of the recoveries of earlier decades.

The United States is not alone in this development; European investment has also been weak. After declining five percent in real terms between 2001 and 2003, euro area nonresidential fixed investment grew only two percent in 2004. The direct impact of this slower growth in the United States and Europe shows that equipment manufacturers did not experience the same sales growth as in previous expansions.

Chart 3: Growth in Capital Investment During Recent Periods of Cyclical Expansion

(Cumulative Increase in Real Nonresidential Investment From Trough to Peak, Trough=100)



Source: Bureau of Economic Analysis ECS/JPC

Part of this slowdown reflects a change in the investment pattern of the manufacturing sector. Manufacturing has traditionally been, and still is, the sector with the most investment in plant and equipment. This investment incorporates new technologies into the production process, promotes new synergies through its linkages to the rest of the economy and improves productivity. However, manufacturing's share of capital investment has begun to slip. From 1987 to 1998, manufacturing's share of equipment and software investment averaged 22.5 percent of the total. In 1999, its share of equipment and software purchases fell below 20 percent for the first time. That share averaged 18.5 percent during the 1999-2002 period and declined to about 16 percent by 2004.[27] Private sector investment overall and manufacturing investment did show some improvement in 2004 although it still did not match 2000 levels. However, industrial equipment investment went up at only half the pace of overall equipment investment. Since manufacturers are one of the main purchasers of such equipment, that is one reason that the sector's share did not improve in 2004.

In 1995 and 1996, manufacturing accounted for about 17 percent of investment in new nonresidential structures. That share fell to only 9 percent by 2001. Then between 2001 and 2003, private sector construction of manufacturing facilities declined almost 45 percent in nominal terms, causing manufacturing's share of investment in nonresidential structures to fall further, to six percent. Some improvement in the pace of new construction spending was seen in 2004, a 10 percent increase in expenditures on manufacturing construction and a very small increase in the share. Expenditures on new construction for manufacturing structures during the first six months of 2005 have averaged 27 percent above the similar period in 2004. The largest year-over-year gains have been in the food and transportation equipment sectors, followed by metals and computers/electronics. However, even those gains leave investment in new construction at levels that are 30 percent lower than in June 2001, in nominal terms. After correcting for inflation, the decline is even larger.

Investment in new capacity is the hallmark of a growing industry that is optimistic about the future. And, it incorporates the latest innovative developments into the productive process. But the pace of capacity expansion (net of closures) has slowed

[27] While the weakness of the manufacturing sector has been a contributor to this outcome, the productivity of manufacturing capital may have been another factor that has influenced this decline. Between 1992 and 1999 (the last full year before the manufacturing recession began), the productivity of manufacturing capital grew about one percent per year. At the same time, capital productivity for the overall nonfarm economy was virtually unchanged. To the extent manufacturers use their equipment more efficiently than other sectors of the economy, less investment is needed to support their output.

markedly in the manufacturing sector. Since the trough of the most recent recession, manufacturing capacity has grown at an annual rate of less than one percent. That compares with a five percent rate during the 1990s expansion and a three percent average annual pace since 1972. In a recent speech, the chief economist of The Manufacturers Alliance said that the slowdown in capacity expansion reflects the lack of investment in new facilities rather than an increased rate of closing old ones.[28]

Chart 4: Capacity Growth by Type of Good Produced
(Cumulative Increase Since 1972, 1972=100)

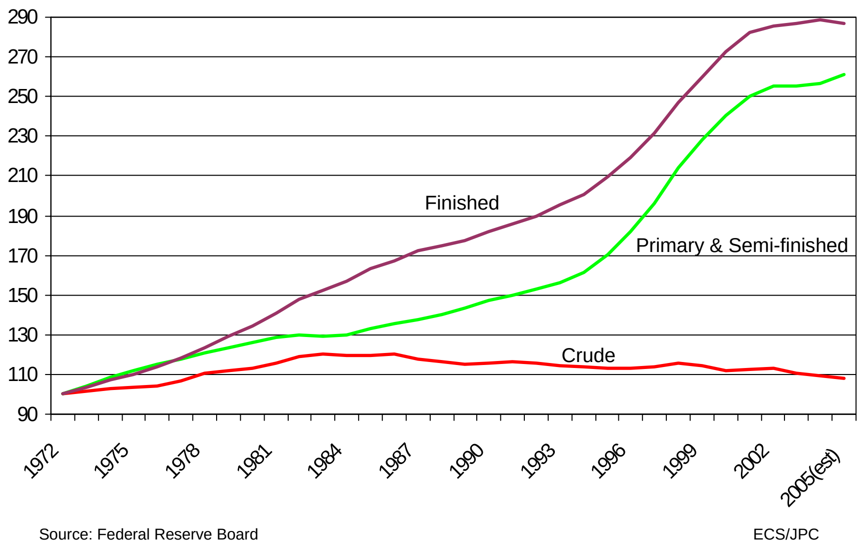


Chart 4 shows that capacity growth has varied significantly between industries grouped by stage-of-process, a classification based on the amount of fabrication that has taken place on the product. An actual decline in capacity has been ongoing since the early 1980s in U.S. capacity to process crude materials for subsequent transformations by the rest of the manufacturing sector.[29] In extractive industries, domestic exploration and productive capacity declined significantly over the past two decades. The total number of mines in the United States declined more than 30 percent between 1980 and 1996, with

[28] "The Dynamics of the U.S. Manufacturing Sector: The Churn of Firms and Jobs," Speech by Daniel Meckstroth, chief economist of The Manufactures Alliance, to the National Economist Club, May 26, 2005.

[29] "Bottleneck Inflation and Growth," by Joel Popkin in *The Rising Tide* edited by Jerry Jasinowski, John Wiley & Sons, 1998.

coal mines being the most impacted. Since 1996, the number of coal mines has declined 25 percent but there has been a small resurgence in the number of metal and non-metal mines in operation.[30]

The United States has become more dependent on foreign nations to supply many important raw materials, now importing more than 50 percent of 42 mineral commodities, all of which are important for manufacturing and strategic military uses.[31] The reliance on imports of important commodities such as aluminum, copper and cement has nearly doubled since 1996. Most prominent, given its potential economic impact, is the U.S. dependence on imported oil, 65 percent of which was imported as of mid 2005. This increases the vulnerability of U.S. manufacturers to supply disruptions. Some of the increase in import dependency reflects dwindling U.S. petroleum and mineral resources. But the decline also reflects the environmental policies that have limited the incentives to development of resources in the United States vis-à-vis some of our trading partners. But, mineral and crude processing capacity abroad is being stimulated to locate closer to the growing customer base, particularly that in eastern Asia.

One-third of U.S. natural gas consumption is used for industrial purposes and an additional 24 percent is used to generate electricity for business and residential use. While the United States is not as heavily dependent on foreign sources for natural gas as it is for oil (it imports about 20 percent of consumption, mostly from Canada and Trinidad), new investment in natural gas facilities will be needed to increase U.S. consumption of that fuel. Proved reserves of natural gas in the Untied States are still increasing in contrast to proved reserves of petroleum.[32] However, U.S. production of natural gas fell in 2004 and the discoveries of new gas fields in the United States were the lowest in 12 years. Twenty percent of the current production of U.S. natural gas comes

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[30] "Operations in the United States, by Primary Activity, 1978-2004," U.S. Mine Safety and Health Administration.

[31] "Mineral Commodities Summaries 2004," U.S. Geological Survey, p. 5.

[32] "Advance Summary: U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves 2004 Annual Report," from the U.S. Department of Energy shows that proved reserves of crude oil decreased 2.5 percent between December 2003 and December 2004 while those for natural gas and natural gas liquids increased 1.8 percent and 6.3 percent respectively.

from the Gulf of Mexico and hurricane damage (starting with Ivan and continuing with Katrina and Rita) has proved the vulnerability of that supply during the past two years.

The United States is the largest importer of manufactured goods in the world and its share of world imports has grown. While trade will be discussed in the next section, the impact on U.S. capacity to produce finished and semi-finished products can be seen from Chart 4. The smaller the share of U.S. demand for locally produced finished goods, the less likely it is that new capacity will be located here. Given the leveling off of crude material capacity growth, U.S. manufacturing capacity growth during the 1990s was sustained by the growth of plants producing intermediate and finished goods.[33] However, that growth in capacity has leveled off. Finished goods capacity has grown 1.9 percent since November 2001 and the capacity for intermediate goods has grown 3.9 percent. There are some bright spots underlying these numbers. Growth in capacity has been focused in the industries that have relatively high rates of R&D, such as computers, semiconductors, communications equipment, chemicals and aerospace. It has been shrinking rapidly in areas such as textiles and apparel. But some additional problem areas are evident. Capacity for producing machinery fell more than 4 percent since the end of the recession, after growing more than 30 percent during the 1991-2001 expansion. Motor vehicle capacity has grown more than 10 percent in the past four years, mainly reflecting plant additions by foreign car makers, but that growth will diminish as the announced realignment and plant closures within that sector begin to take place.

The rise in manufacturing output, though modest by historical standards, nonetheless outpaced sluggish capacity growth over the past two years, leading to an improvement in total capacity utilization. Finished goods capacity utilization is now at 78 percent and the utilization of intermediate goods capacity is slightly higher, 82 percent. Neither has reached the point at which capacity expansions were triggered during the late 1990s. While it is difficult to put a precise number to such trigger points, utilization rates in 1995 were 86 percent for intermediate goods and 79 percent for finished goods. It appears that capacity utilization has to move to higher levels to prompt

[33] Federal Reserve Board Industrial Production Database, capacity by stage of process.

substantial investment in new capacity. But the present situation, in which considerable output is imported despite the availability of local production facilities, is clearly disturbing, as it reduces incentives to expand U.S. capacity. That in turn means that innovations embodied in new plants and equipment are not being introduced into the production process.

Rapidly growing economies, however, are the site of new plants using many of the latest technologies available. These economies have large populations with increasing demands for consumer goods, so those expansions are not necessarily destined for the export market. However, the distribution of that expansion does provide some insights into the growth of world manufacturing capacity. The Chinese statistical agency reports a doubling of investment (in nominal terms) in manufacturing plants and equipment between 2001 and 2003 and 93 percent of those expenditures were for new or expanded facilities.[34] The distribution of the 2003 expenditures on new construction by industry show that 16 percent of expenditures were for new facilities to process or manufacture food products, and for apparel and textile manufacture. An additional 25 percent of the expenditures went toward mineral, primary and intermediate metal manufacturing. However, almost a quarter of the investment went into the machinery and equipment industries, and about 18 percent financed new manufacturing facilities for chemicals and medicines.

The manufacturing industrial production index for India also implies an expansion of capacity. The overall manufacturing production index has grown at a 7.5 percent average annual rate between November 2001 and November 2005. The eight-percent increase in the overall manufacturing index between November 2004 and November 2005 reflects an underlying increase of five percent in basic goods, two percent in intermediate goods, and 12 percent in capital goods.[35]

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[34] *China Statistical Yearbook, 2004*, National Bureau of Statistics of China, Tables 6-9 and 6-10.

[35] *Index of Industrial Production Report*, Central Statistical Organisation, Ministry of Statistics and Programme Implementation, July 12, 2005.

Restructuring of industries and a loss of market share in some industries is a part of the dynamic economic process. But lagging capacity growth in a range of manufacturing sectors is a signal of a potentially more serious problem that has implications for long-run economic prosperity.

C._Impact of U.S. Manufactured Goods Loss of Share in Global Trade

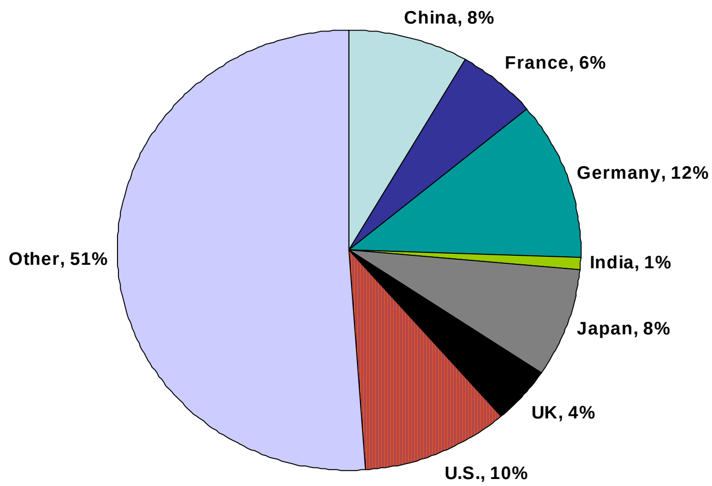
Global trade patterns are best seen through an analysis of exports. U.S. exports have recovered from their sharp decline during 2001 and 2002. The 2004 value of U.S. exports of merchandise reached a level that was above its value in 2000. Nonetheless, the United States lost its leadership in world merchandise exports to Germany in 2003 and the German lead widened in 2004 as its exports (in dollar terms) grew eight percentage points faster than those of the United States. The U.S. supplied about 12 percent of the world's merchandise exports during the 1994-2001 periods, but its share fell to 9.6 percent in 2003 and further, to 9.0 percent, in 2004. This decline in share reflects both a weakness in volume, especially during the recession, and a 15 percent decline in the value of the U.S. dollar between the end of 2001 and 2004.

The picture for exports of manufactured goods is similar, since they account for three-quarters of U.S. merchandise exports. The value of world exports of manufactured goods has more than doubled over the past decade. The United States's share during the 1994-2001 period was relatively stable, averaging about 13 percent. Since then its share has declined. In 2003, the U.S. share was 10.7 percent and was down to 10.2 percent by 2004 (*See* Chart 5). That compares to Germany's 11.7 percent share in 2004. China's share has doubled in the past few years rising from four percent in 1999 to 8.3 percent in 2004. U.S. exports of manufactured goods totaled $669 billion in 2004; that was an improvement of more than 13 percent from 2003 but was still only three percent above the level of 2000.[36]

[36] WTO world trade database.

Despite the absolute growth in U.S. exports, the merchandise trade deficit has been negative since 1976, as goods imports, particularly consumer goods, have grown much faster than exports. Goods exports as a share of U.S. GDP peaked at about eight percent in 1997, retreated to about 6.5 percent in 2002 and 2003, and recovered to a bit more than seven percent in early 2005.[37]

Chart 5: World Exports of Manufactured Goods in 2004
Share of Total

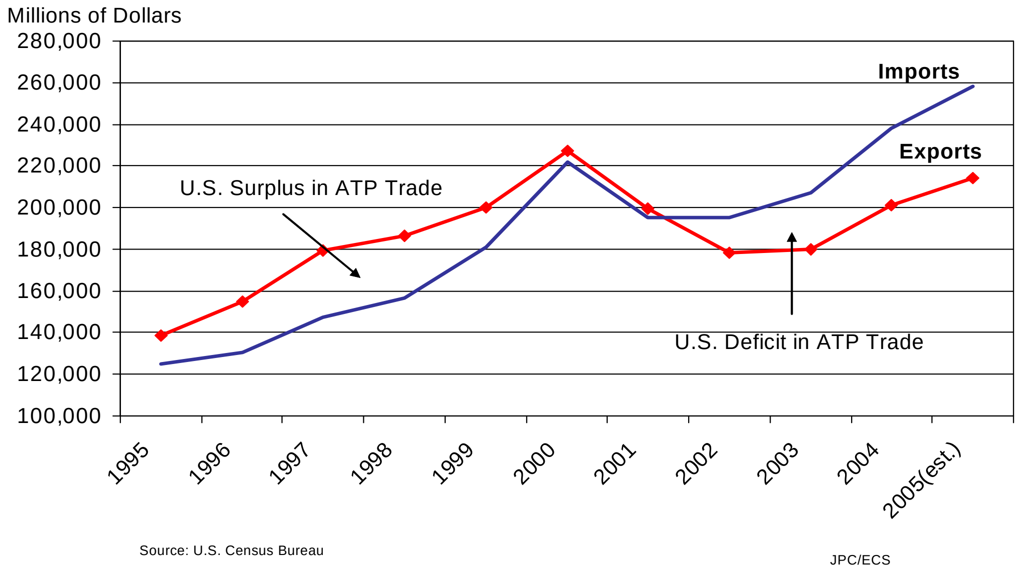


Source: World Trade Organization JPC/ECS

Also troubling in the loss of the total goods export share, is the loss of our share of machinery and equipment exports. Capital goods (including automotive) were 56 percent of U.S. goods exports in 2000, a high point for the decade. But, that share slipped to 50 percent by the first half of 2005. Even earlier, the United States' share of world machinery and equipment exports had begun to decline. The United States supplied 16.3 percent of world machinery and equipment exports in 1997; that slipped to 15.7 in 2000, and was down to 11.3 percent by 2004.

[37] Goods imports equal more than 13 percent of GDP during the first half of 2005, up from about 10.5 percent in 1997.

Table 6: U.S. Imports and Exports of Advanced Technology Products



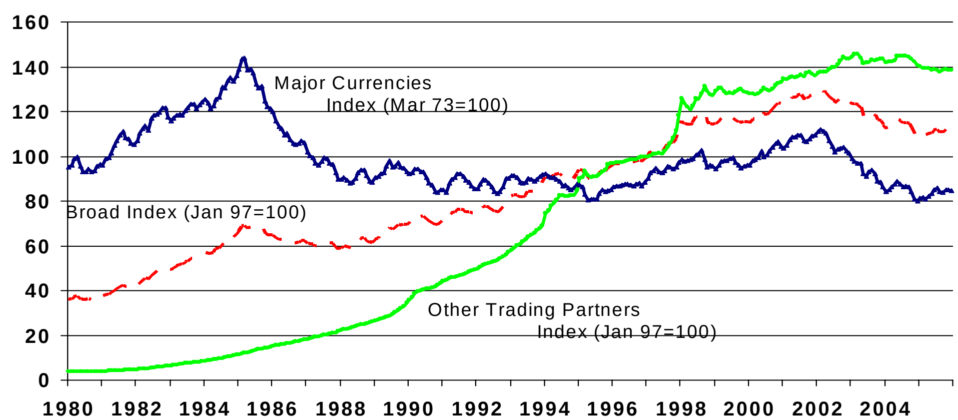
Another category that perhaps surprisingly, shows a trade deficit is what the Census Bureau defines as Advanced Technology Products (ATP). These are the cutting-edge products thought capable of offsetting our loss of lower-tech manufacturing. There is a significant overlap between these products and the machinery and equipment category discussed above, but not all ATPs are equipment and not all equipment is considered an ATP.[38] The United States exports and imports of these products are shown in Chart 6. In 1999, the United States ran a trade surplus for these products of almost $20 billion. While its trade surplus was smaller in 2000 and 2001, the United States was still exporting about $5 billion more of these goods than it imported. However, by 2002 the trade balance for these products turned negative as the U.S. imported almost $17 billion more ATPs than it exported. That deficit has grown each year since then; in 2003 the deficit for ATP was $27 billion, $37 billion in 2004, and during the first 11 months of 2005, the U.S. deficit totaled $41 billion. The U.S. still has a trade surplus in the areas of biotechnology, electronics, flexible manufacturing, aerospace and weapons. But it is

[38] Advance Technology Products are defined as those in the following areas: biotechnology, life sciences, optoelectronics, information and communications, electronics, flexible manufacturing, advanced materials, aerospace, weapons and nuclear technology. These are areas where the United States has made significant R&D expenditures and where many innovative processes and products are developed.

importing more than it is exporting in the other ATP categories and has large trade deficits in life sciences, information/communications and optoelectronics, resulting in a net deficit.

The strong U.S. dollar overseas has been blamed for handicapping export growth and encouraging the growth of imports. The weakening of the dollar over the past four years has helped U.S. goods exporters. Between its high point in February 2002 and early January 2006, the dollar has fallen 15 percent on a trade-weighted basis. That, in addition to an improved worldwide economic situation, helped fuel the increased goods exports in 2004. But the balance of trade impact of the dollar's decline has not been as large as some had hoped. The U.S. trade deficit in goods increased from $482 billion in 2002 to

Chart 7: Nominal Dollar Indexes - Major Currency, Broad Index, Other Trading Partners Index



Source: Federal Reserve Board

ECS/JPC

$547 billion in 2003, and then to $665 billion in 2004. In 2005, the deficit piled up at an average rate of more than $60 billion per month and exceeded $700 billion for the year by November.

The lack of improvement in the trade deficit is partly because the decline in the value of the dollar comes mostly from its 25-percent depreciation against the seven “major” currencies of the world — those that are traded on exchanges outside of their own countries.[39] But those countries only account for about 53 percent of U.S. exports and 45 percent of U.S. imports.

If one looks at exchange rates applicable to the “Other Important Trading Partners” of the United States, as shown in Chart 7, it is clear that the dollar has changed little in value against them since February 2002, down barely one percent.[40] Those countries supply 44 percent of U.S. merchandise imports, but they buy only 38 percent of U.S. exports. The differential for China is even larger. China bought four percent of U.S. exports in 2004, but was the source of 13 percent of U.S. imports; therefore, trade with China accounted for 21.9 percent of the 2004 U.S. merchandise trade deficit.[41]

The Chinese currency had been pegged to a precise exchange rate with the U.S. dollar for many years. In late July, China unpegged its currency from the dollar and instead began controlling its value against a basket of currencies.[42] However, while this increased slightly the value of its currency against the dollar, the initial revaluation and the movement since then has been so small that it is unlikely to have much impact on the trade balance between the United States and China. Since some analysts estimate the *renminbi* (also referred to as the yuan) is overvalued by as much as 40 percent, there is significant pressure for a further revaluation. China has indicated some further upward revaluation, but not a free float, is in the offing. But it has also indicated it will diversify its foreign exchange holdings. [43]

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[39] Major currencies are defined as the Euro, Canadian dollar, Japanese yen, British pound, Swiss franc, Australian dollar and Swedish krona. The Federal Reserve Board’s “Other Important Trading Partners” index is made up of the currencies of China (including Hong Kong), Mexico, South Korea, Taiwan, Malaysia, Singapore, Brazil, Thailand, India, Philippines, Israel, Indonesia, Russia, Saudi Arabia, Chile, Argentina, Columbia and Venezuela.

[40] Many of the currencies in this index are pegged to the dollar and the exchange rate for those currencies show little month-to-month variation. The other currencies in the index tend to devalue against the dollar.

[41] While China bought a relatively small share of U.S. exports, China’s total imports have boomed over the past three years, growing 32 percent per year on average, much faster than the nine percent per year increase in U.S. imports. In 2004, China imported $561 billion of merchandise, about one-third of the value of U.S. imports and Hong Kong imported an additional $273 billion of merchandise (although some of those imports are undoubtedly transshipped to other parts of China.)

[42] “China Revalues Yuan,” CNN, July 21, 2005.

[43] China is a major holder of U.S. Treasuries, and as it acquires more dollars through trade it buys more Treasuries. That is a logical outcome when its foreign exchange activities are focused on holding its

While the direction if not the magnitude of the U.S. merchandise deficit has not been unanticipated, the conventional wisdom has been that as the U.S. economy shifted to services, service exports would compensate for weaker goods exports. But that has not happened. U.S. service exports grew 72 percent from 1994 to 2004 (and 45 percent in constant dollar terms), but they were still less than half the size of goods exports in 2004. And, the relatively small trade surplus in services has fallen by one-half over the past 10 years.

The United States has competition in service exports as well as in goods exports. It is the largest exporter of commercial services to the world, accounting for 17-18 percent of the total during the 1990s and early 2000s. However, its share has fallen during the past three years and was down to 15 percent in 2004. In addition, the United States is both a major exporter and a major importer of some of the services with the largest total value, such as transportation and travel services. That will continue to be true. Consequently, the United States cannot depend solely on trade in services to offset a serious decline in goods exports. In addition, U.S. providers of business services are facing increasingly strong competition as foreign producers of services begin to staff U.S. call centers and provide programming services to U.S. companies. These jobs represent U.S. service imports and offset U.S. service exports. Consequently, the solution to the trade deficit is unlikely to be found solely with service sector exports.

Based on the World Trade Organization's statistical database, the United States continues to be the world's leading importer of merchandise, accounting for $1.5 trillion or 16 percent of the world's merchandise imports in 2004, more than twice the value of the number two importer, Germany.[44] Imports have been a positive force in the United

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currency in a strict relationship to the dollar. However, if its foreign exchange activities are more wide ranging (such as using a basket of currencies including the euro, yen and won, as well as the dollar, in its foreign exchange activities) China may decide to hold a larger percentage of its assets in bonds valued in different currencies.

[44] Part of the growth in the merchandise trade deficit can be attributed to the growing purchases by U.S. "Original Equipment Manufacturers" (OEMs) of foreign-produced parts and components for their products. A measure of this hollowing out of the supply chain can be found in the statistics on "related party trade" — that is, imports to the United States from U.S.-owned foreign affiliates or from foreign companies to

States. The influx of inexpensive goods has helped keep prices down and encourage consumer spending among all income levels.[45] However, when trade becomes too one-sided, it can slow economic growth and increase the potential for economic instability. To purchase these goods, large quantities of U.S. dollars flow overseas. So far, the countries receiving those dollars have frequently used them to purchase our Treasury debt, buy U.S. assets and purchase oil. However, if those choices were to change, as China has hinted, the resulting adjustment process could cause interest rates to rise in the United States and the dollar to fall significantly. Consequently, it is important for the United States to maintain its ability to produce new and better goods and services so that those dollars can also be used to purchase more U.S. exports.

These trade developments have prompted some economists to revisit the assumption that the law of comparative advantage will cause all countries to benefit from free and open trade. They have pointed out the assumptions underlying that hypothesis may no longer be tenable in today's global economy.[46] That "law" is based on the assumption that a country's labor, capital and technology do not move offshore. "If these factors move abroad to where cheap labor makes them more productive, absolute advantage takes over from comparative advantage."[47] Even the first American Nobel Laureate in Economics, Paul Samuelson, wrote recently in a scholarly journal that nothing in the law of comparative advantage denies that "new technical Chinese progress in goods in which America previously had a comparative advantage can, all else being equal, permanently lower measurable per capita U.S. real income."[48]

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their U.S. affiliates. In 2004, the Department of Commerce estimated that $698 billion, or 48 percent of all U.S. merchandise imports, fell under this category of trade.

[45] In a recent article titled "Are We Underestimating the Gains From Globalization for the United States?" Broda and Weinstein posit that U.S. consumers have also seen significant welfare gains from the expanded variety of goods that have become available through international trade. In *Current Issues in Economics and Finance*, Federal Reserve Bank of New York, Vol. 11, No. 4, April 2005.

[46] The hypothesis never claimed a country could still hold on to its share of a growing pie.

[47] "The Harsh Truth About Outsourcing," by Paul Craig Roberts, *BusinessWeek*, March 22, 2004.

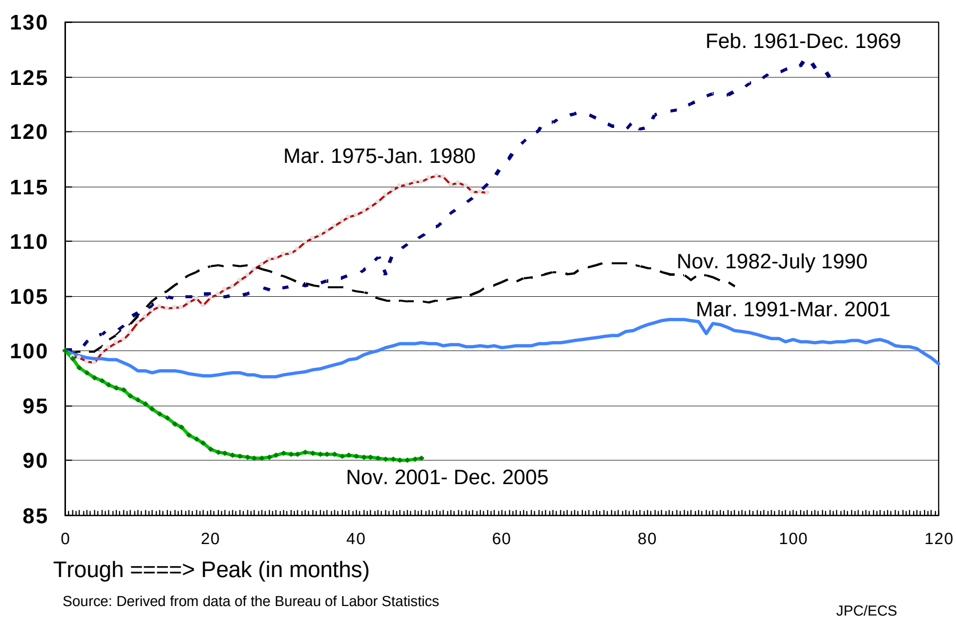
[48] "Where Ricardo and Mill Rebut and Confirm Arguments of Mainstream Economists Supporting Globalization," by Paul A. Samuelson, *Journal of Economic Perspectives*, Vol. 18, No. 3, Summer 2004, pp. 135-146.

But more fundamental to the outlook for the U.S. trade deficit is the reality that we have shifted from a producing economy to a consuming economy. Our ability to stay on that path depends, like a retiree, on how long our wealth will last. The potential adjustment processes to a more sustainable situation could be gradual or very rocky.[49] However, the United States' ability to generate more wealth will be an important factor in its ability to adjust to the changes and manufacturing makes a vital contribution to that process.

D._Impact on the Manufacturing Workforce

Manufacturing has traditionally been a sector providing well-paying, full-time jobs, many that provide scheduled overtime as well. However, the availability of such jobs is shrinking. At 14.3 million workers, employment in manufacturing is at its lowest

Chart 8: Employment in Manufacturing During Recent Periods of Cyclical Expansion
(Cumulative Increase in Payroll Employment From Trough Month to Peak Month, Trough=100)



[49] For some possible scenarios, see *Three Billion New Capitalists: The Great Shift of Wealth and Power to the East*, Clyde Prestowitz, Basic Books, Cambridge Massachusetts, 2005, p. 193 and "Counting on a

point since 1950 when U.S. GDP was about three percent of its current dollar size.

As can be seen from Chart 8, manufacturing employment has usually increased during expansions. In the major expansions of the 1960s, 1970s and 1980s, manufacturing employment had increased 10 percent on average after 49 months. The 1991 recovery was different, manufacturing employment showed less than a one-percent increase after the first 49 months of that recovery. That was one reason the early part of that expansion was referred to as the “jobless recovery.” During the first two years of this recovery, manufacturing employment continued to fall, declining almost 10 percent by the end of 2003. In the past two years, those declines have leveled off but employment in this sector has shown little growth, registering positive gains in only nine months, and has declined by 10 percent since the recession ended.

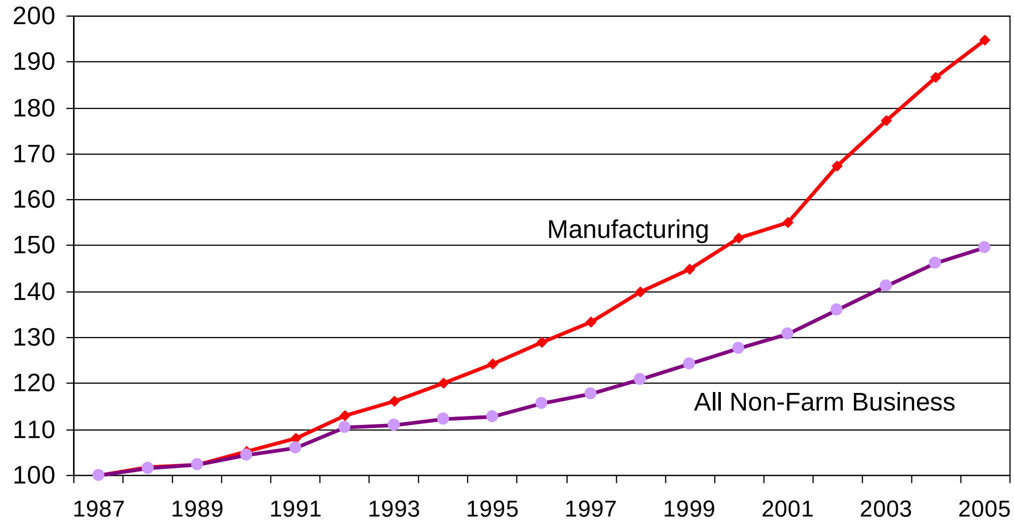
During the 2001 recession, overall employment declined by 1.2 percent while manufacturing employment declined 6.5 percent. Manufacturing jobs made up almost 70 percent of the total jobs lost during March to November 2001. However, manufacturing had already been losing jobs well before the recession started whereas the rest of the economy was generating employment growth. Manufacturing employment had fallen four percent from its high point during the 1991 economic expansion (March 1998) before the recession officially began.[50] While this job loss has been painful, it also reflects one of the major benefits that manufacturing has provided to the economy as a whole: significant productivity growth.

A comparison of Chart 2 and Chart 8 shows that the decline in manufacturing employment significantly overstates the impact on production in the manufacturing sector. That is because the productivity of the manufacturing workforce has grown significantly faster than has productivity in the economy overall.

Miracle With U.S. Debt,” David Wessel, *The Wall Street Journal,* September 29, 2005, p. A2.

[50] The number of manufacturing firms declined by about 6.5 percent in recent years. Between 1998 and 2002, the U.S. Census Bureau estimates that the number of U.S. manufacturing companies declined from 318,537 to 297,873.

Chart 9: Labor Productivity Growth Since 1987
Manufacturing and All Private Non-Farm Business



As Chart 9 shows, labor productivity growth in manufacturing has outpaced that of the United States as a whole since 1992 and has grown significantly faster during this recovery. Since the recession ended, manufacturing labor productivity has grown at an annual rate of 5.8 percent. That compares to 3.4 percent for the non-farm economy as a whole, a rate which includes the results for manufacturing. This differential reflects the continuation of a longstanding trend. From 1991 to 2001, manufacturing labor productivity increased at an average annual rate of 3.7 percent and helped boost the productivity rate of the non-farm economy as a whole to 2.1 percent. This strong rate of growth in productivity has helped U.S. manufacturers stay competitive. Unit labor costs in the manufacturing sector have grown less than half a percent per year since the end of the recession in 2001.

Table 1: Year-to-Date 2005 Average Manufacturing Employment in Thousands (States Arranged by Employment Size)							
State	YTD 2005 Employment	Percent Change 2001-04	Percent Change 2004-05	State	YTD 2005 Employment	Percent Change 2001-04	Percent Change 2004-05
California	1536.0	-14.2%	0.2%	Kansas	178.7	-9.7%	1.3%
Texas	888.7	-13.4%	-0.1%	Mississippi	178.1	-10.7%	-0.7%
Ohio	822.1	-13.5%	-0.3%	Arizona	176.2	-12.8%	0.2%
Illinois	692.3	-14.5%	-0.7%	Colorado	153.5	-15.0%	-0.7%
Pennsylvania	682.9	-15.8%	-1.2%	Louisiana	149.2	-11.4%	-2.0%
Michigan	674.4	-15.1%	-3.1%	Maryland	139.3	-15.1%	-2.4%
New York	581.5	-15.8%	-2.4%	Oklahoma	141.1	-16.5%	-0.5%
North Carolina	574.9	-17.7%	-0.8%	Utah	117.0	-5.8%	1.8%
Indiana	573.1	-7.0%	0.2%	Nebraska	99.7	-9.1%	-1.0%
Wisconsin	503.1	-10.4%	0.3%	New Hampshire	81.1	-17.6%	1.0%
Georgia	440.3	-10.7%	-1.1%	West Virginia	62.6	-12.7%	-0.7%
Tennessee	411.0	-9.4%	-0.1%	Idaho	62.0	-10.0%	0.9%
Florida	390.7	-10.3%	0.8%	Maine	61.8	-15.4%	-2.1%
Minnesota	347.4	-9.5%	1.4%	Rhode Island	55.2	-16.1%	-3.0%
New Jersey	330.2	-15.5%	-2.6%	Nevada	47.2	4.3%	2.9%
Missouri	313.8	-9.5%	0.5%	South Dakota	39.8	-4.9%	2.2%
Massachusetts	312.9	-19.2%	-0.3%	Vermont	37.3	-18.9%	0.8%
Virginia	298.1	-12.3%	-0.4%	New Mexico	35.8	-12.2%	-0.3%
Alabama	295.7	-10.6%	1.6%	Delaware	33.9	-11.4%	-2.8%
Washington	265.4	-16.6%	0.7%	North Dakota	25.2	2.1%	2.7%
Kentucky	264.4	-9.6%	0.2%	Montana	19.3	-10.7%	1.0%
South Carolina	264.3	-14.4%	-1.6%	Hawaii	15.4	-6.1%	0.0%
Iowa	225.9	-7.2%	1.4%	Alaska	13.8	4.3%	12.8%
Oregon	204.7	-7.5%	2.6%	Wyoming	9.5	-5.0%	-0.1%
Arkansas	202.7	-10.1%	-0.6%	District of Columbia	2.5	-26.5%	-0.9%
Connecticut	197.7	-12.9%	0.1%				
Source: Bureau of Labor Statistics, U.S. Department of Labor							

Manufacturing jobs are present in every state in the union and the District of Columbia. All but three of those areas (Alaska, Nevada and North Dakota are the exceptions) lost manufacturing jobs between 2001 and 2004; that loss averaged 11.5 percent. Since then there have been signs of manufacturing employment stabilizing in many states. Twenty-three states show increases in manufacturing employment between 2004 and 2005 and only 12 had declines of more than one percent. Table 1 presents manufacturing employment for 2005 for each state, its cumulative percent change between 2001 and 2004 and the percentage change in employment since 2004.

For manufacturing workers with three or more years of tenure at their job, plant closures accounted for 53 percent of the job displacements during the period from January 2001 through December 2003.[51] That compared with 40 percent for the non-manufacturing sectors of the economy. On average each year from 1993 through 1998, 177,000 manufacturing workers with three years or more of tenure lost their jobs due to plant closures. From January 1999 through December 2001, that rate increased to 230,000 workers per year and for the period January 2001 through December 2003, the rate averaged slightly over 300,000.[52] The rate of reemployment for long-tenured employees (three years or more at their jobs) in manufacturing is also relatively low. Less than half of those workers returned to manufacturing jobs. The rate of re-employment in nondurable manufacturing is particularly weak, with only about a quarter of those losing jobs in non-durable manufacturing re-employed in the same industry.[53] Long-tenured, full-time manufacturing employees, who do find new full-time jobs in any industry, take a pay cut. In 2004, that pay cut averaged about 16 percent for manufacturing compared to 11 percent for all nonagricultural private sector workers.

Manufacturing continues to be a well-paid industry for the workers it still employs. Annual pay per worker averaged $47,859 in 2004, up 11.4 percent from 2001. That compares to an average annual pay of $39,127 for all private industry employees in 2004, an increase of 8.2 percent from 2001. Manufacturing jobs provide better benefits than the average private sector job as well. In 2004, benefits per hour worked averaged $9.65 in manufacturing and $6.76 in the overall private sector.[54] However, that differential also reflects the higher percentage of full-time workers in manufacturing than

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[51] The reason for plant closures cannot be identified in these surveys. Consequently, all of these job displacements cannot be linked to outsourcing overseas. However, many of the industries with increasing import penetration shares are also industries in which a large percentage of the job losses are due to plant closures.

[52] *Displaced Workers Survey*, Bureau of Labor Statistics, U.S. Department of Labor.

[53] These rates cover workers who lost their jobs due to plant closures, lost shifts or slack work. Consequently, the rates of re-employment among workers whose jobs were lost due to plant closures is undoubtedly somewhat lower than these.

[54] *Employer Costs for Employee Compensation*, Bureau of Labor Statistics, Department of Labor. Benefits are calculated per hour worked and therefore include leave benefits and premium pay as well as insurance and retirement benefits.

in the economy overall.[55] Eighty-nine percent of manufacturing workers were on full-time schedules in 2004 compared with 76 percent of the overall economy. Only the mining sector had a higher percentage of full-time workers. Benefits per hour of full-time workers are $9.87 in manufacturing compared to $8.03 in the overall private sector.[56] Manufacturing jobs also have more paid overtime.[57] Manufacturing production workers averaged 4.6 hours of overtime per week in 2004, up from 4.0 hours in 2001, but still well below the 5.1 hour average of 1997. During the first nine months of 2005, overtime hours for manufacturing workers averaged 4.5 hours per week.

Another reason for higher wages and benefits in manufacturing reflects its older, more experienced workforce. In 2004 the median age of workers in the manufacturing sector was 42 compared to 40.5 for the workforce overall. In the past four years, the median age in manufacturing has increased by 1.5 years. Tenure at manufacturing jobs rose by about one year during this period. Both of these are reflections of the job losses in manufacturing since seniority often plays a role in determining layoffs and the small numbers of new, younger workers that are being added to the payrolls. An experienced workforce is generally a positive factor in promoting productivity growth and has been one factor in manufacturing's productivity success story.

Manufacturing offers job opportunities across the educational spectrum—employing more than its relative share of the workforce with no more than a high school diploma while also employing a large number of college-trained employees. In 2004, manufacturing had on its payrolls 15 percent of the workforce without a college degree. It was the largest employer of employees with that level of educational attainment. Manufacturing, however, also employed 10 percent of the workforce with at least an associate's degree.[58] The only sectors that employed a larger number of college-educated employees were the professional services, education and health sectors.

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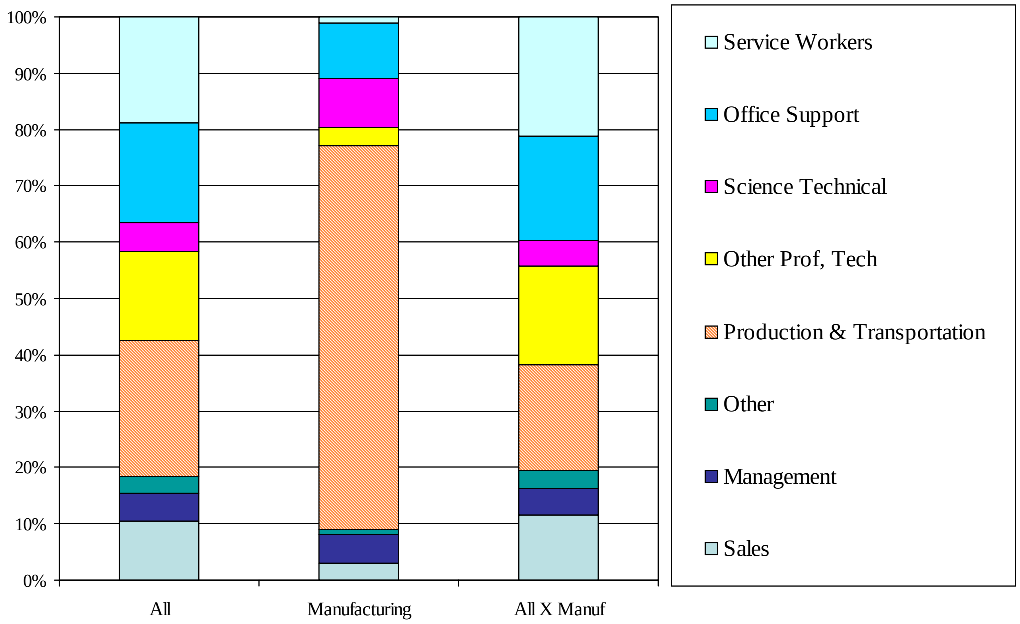
[55] Full-time workers are much more likely to be eligible for benefits than part-time workers in all industries.

[56] *Employer Costs of Employee Compensation*, Bureau of Labor Statistics, U.S. Department of Labor.

[57] In 2004, about $.59 cents of the average hourly benefits were related to paid overtime.

[58] Current Population Survey, 2004, Bureau of Labor Statistics.

Chart 10: 2004 Occupational Mix for Overall Economy and Manufacturing
(Percent of Each Occupation in Total Workforce)



Source: Bureau of Labor Statistics

JPC/ECS

The differential between the distribution of workers in manufacturing and in the rest of the economy can be seen from Chart 10. Production, installation, maintenance and transport workers made up the bulk of the manufacturing workforce in 2004. The median wage for that group was slightly less than $30,000. Manufacturers had a similar percentage of management employees with similar pay rates as the rest of the workforce. However, the non-manufacturing workforce has a larger percentage of sales workers, whose median wage in 2004 was about $22,000, administrative support workers with a median wage of $28,000, and service workers whose median wage was below $20,000.

Despite its good wages, benefits and available training, new workers hesitate to plan a career in manufacturing. That is because of a heightened perception that the sector, long the hallmark of good career jobs, now presents a picture of job instability while at the same time job openings are few. Such views are reinforced by the BLS' *Occupational Outlook Handbook*, which shows that demand for workers in production occupations is expected to grow only 3.2 percent over the 10-year period of the projections. This contrasts with overall employment growth of 14.8 percent —

1.4 percent per year. This dismal job outlook offers one explanation for why manufacturers are having problems recruiting skilled workers in a labor market in which the unemployment rate, until recently, has been hovering above five percent. Clearly, one casualty of the slow growth of manufacturing is the diminished size of its workforce, once the envy of the world. Just like in the case of new investment discussed above, shrinking demand discourages work force entry.

The older median age in manufacturing poses another problem. Since there are few entrants to manufacturing, there may be a shortage of workers with the skills necessary to take over the jobs of retiring workers. BLS identified about 11 percent of the manufacturing workforce in 2004 as being in jobs that required long-term on-the-job training, an additional 10 percent of the workforce was in occupations requiring either prior work experience or a college degree combined with prior work experience. An additional 41 percent of the workforce was in jobs that required up to one year of on-the-job training to be proficient. According to the NAM's Center for Workforce Success, some experts predict that the U.S. economy overall will be experiencing a shortage of upwards of 13 million qualified employees by 2020.[59]

But the pay and training of production workers is not the only human capital area in which manufacturing makes a significant contribution to the U.S. economy. In recent years, manufacturing has employed about a quarter of scientists and related technicians and about 40 percent of engineers and engineering technicians. This highly educated and skilled group is very important to the R&D process. Developments in this labor market are discussed in the R&D section that follows.

E._U.S. World Leadership in R&D at Risk

i) The United States' Place in World R&D Investment

The United States is still the undisputed world leader in total amount spent on R&D investment. It is responsible for more than 40 percent of all R&D expenditures

[59] "In Search of Skilled Employees for America's Future," by Jerry Jasinowksi, May 24, 2005.

among the Organisation for Economic Co-Operation and Development (OECD) countries, the major developed countries of the world. The U.S. manufacturing sector is an important contributor to this process, directly performing more than 40 percent of U.S. domestic R&D. Among the 1,000 firms in the world that spend the most on R&D, 42 percent of them are U.S. companies.[60] Among the four leading factors of technological competitiveness identified by researchers at the Georgia Technology Research Center, the United States is the leader in three.[61]

However, the United States cannot take that leadership for granted. The manufacturing sector has always been instrumental in generating the U.S. R&D investment and it will play that role in other countries as they expand their manufacturing sectors. The intrinsic interrelationship between manufacturing and R&D is just too strong for that not to happen. Given recent trends in manufacturing output growth overseas and the relatively modest growth in domestic manufacturing output, it is inevitable that the U.S share of worldwide R&D will shrink. As foreign R&D grows, there will be increased demand for the inputs to the innovation process in those countries. They will develop more advanced educational systems and turn out increasing numbers of trained workers in the science and engineering fields as well.

A recent National Bureau of Economic Research paper by Richard Freeman makes two observations. The first is that "trade models designed to explain the extensive trade among advanced countries with similar factor endowments posit that the trade occurs because countries gain advantages from being the first-mover on new technologies, which require R&D resources, and/or from increasing returns, say through learning as output increases or through positive spillovers from one firm in a sector to another. In these models, countries make their comparative advantage by investment

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[60] "The 2005 R&D Scoreboard," United Kingdom Department of Trade and Industry, October 2005, p.9. These data are compiled from "company annual reports & accounts" and the lack of such standardized reporting mechanisms in some countries may account for the DTI finding "no evidence of substantial R&D spending in Chinese or Indian companies."

[61] *Science and Engineering Indicators — 2004,* NSF, 2004, Appendix Table 6-5 identifies the four major factors as: 1) National orientation; 2) Socioeconomic Infrastructure; 3) Technological Infrastructure; and 4) Productive Capacity. The United States leads in all but national orientation where it is fourth.

decisions and technological prowess."[62] He also posits that large populous developing countries, such as China and India, are capable of what he terms "human resource leapfrogging" whereby they employ large enough numbers of scientists and engineers in high-tech vanguard sectors to threaten the leadership position of those sectors previously held by the developed countries.[63] The processes whereby the developing countries educate their workforces and move forward into more technologically challenging areas is the natural outgrowth of economic expansion.

As other countries grow and industrialize, they will challenge U.S. leadership. That does not mean that the United States cannot continue to be a leader in world R&D. Its R&D investment relative to U.S. GDP need not decline. Nonetheless the United States does rank behind a number of other competing countries in the share of its GDP devoted to developing new goods and processes. The United States spent 2.6 percent of GDP on R&D in 2003, a share that has changed little over the past decade. That is about the same as Germany (2.5 percent) and South Korea (2.6 percent), more than the U.K. and Canada (1.9 percent), but less than Japan (3.4 percent). Some developed countries spend an even larger share of their GDP on R&D. Sweden, Finland and Israel each spends 3.5-4.5 percent of GDP on R&D.

Chinese spending on R&D is a smaller share of its GDP but is increasing quickly. While in 1998 China spent only about 0.7 percent of GDP on R&D, by 2002 it was spending 1.2 percent of GDP. That rising percentage of a rapidly increasing GDP (Chinese GDP has been growing about nine percent per year in real terms) represents a significant surge in R&D spending. In its latest report on R&D, the OECD reports that China is now the third largest R&D performer behind the United States and Japan and has the second largest number of researchers, behind only the United States.[64] If recent trends

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[62] "Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?" by Richard B. Freeman, NBER working paper No. 11457, National Bureau of Economic Research, June 2005, p. 19.

[63] Freeman, p. 21.

[64] *Science, Technology and Industry Scoreboard 2005,* Organisation for Economic Co-operation and Development, October 2005.

in Chinese R&D growth continue, it will become a world powerhouse in innovation and will increase its share of the world production of higher value added goods.[65]

Thus, the United States cannot become complacent if it wants to maintain a leadership position in R&D and innovation. An effective R&D base and well-educated workforce are vital for the United States to maintain a competitive position in the world, as well as adequate defense and homeland security capability. A strong and growing domestic manufacturing base is the linchpin in nurturing and maintaining R&D and an educated workforce.

ii) The Unites States' R&D Investment

Total U.S. expenditures for domestic R&D were about $294 billion in 2003. While that reflects an average annual growth rate of 5.9 percent in nominal terms over the past decade, growth has averaged only about three percent annually since 2000. Total domestic R&D funding has increased about one percent per year, after correction for inflation, since 2000.

Business performed 70 percent of total R&D, a share that has declined from 75 percent in the late 1990s.[66] Manufacturing businesses performed $123 billion of domestic R&D in 2003, 42 percent of total U.S. R&D.[67] That share is down about 10 percentage points from the late 1990s although, in reality, the decline in the share of manufacturing-related R&D may not be quite that steep.[68]

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[65]One reason for China's R&D record is apparent in Chinese manufacturers' responses to a recent survey by *IndustryWeek*. When asked to identify the focus of their marketing strategy, the second most frequent response was innovation, preceded only by high quality, itself enhanced by innovation. U.S. manufacturers, when asked the same question, put innovation much further down the list (at number seven). "Manufacturers Like Us," *IndustryWeek*, November 1, 2004.

[66] This includes the federally funded research and development centers that are managed by private industry.

[67] "Increase in U.S. Industrial R&D Expenditures Reported for 2003 Makes Up for Earlier Decline," Raymond Wolfe, *Info Brief*, NSF06-305, National Science Foundation, December 2005.

[68] There are three reasons why manufacturing-related R&D may not have fallen as sharply as the data indicate. The first is that a substantial portion of funding in the trade sector is actually being done for manufacturers. Companies that manufacture goods do not always show up in these statistics as manufacturers. In some cases, because their workforce is more heavily weighted toward their marketing and sales functions, a company may be classified in the trade sector when its R&D activities are primarily focused on its manufacturing activities. NSF has determined that the bulk of R&D in the trade sector in

The distribution of R&D funding has changed over the past decade. Federal funding of R&D fell from about 37 percent in 1993 to 25 percent in 2000. The share of funds provided by private industry rose over that period. Since 2000, the federal share of funding has rebounded to almost 30 percent in 2003 while the industry share has declined. The decline in the share of total R&D funded by the federal government during the 1990s reflects reduced spending for defense and space-related research.[69] Federally funded civilian research has increased slightly as a share of total R&D. Federal funding of non-defense R&D is heavily weighted toward the health sector. Preliminary 2006 budget authority data indicate that almost 55 percent of federal non-defense R&D goes for health-related research, 15 percent goes for space research, and only 12 percent for basic and general science research.[70] Academia and nonprofits provide less than five percent of all funding for R&D. However, colleges and universities play a vital role in the innovation process because the bulk of the basic research in the country is performed there, 55 percent of it in 2003. But most of the funds that support that work are provided by government sources.

Private industry has provided the bulk of the funds for all R&D over the entire decade. In 1993, industry provided 58 percent of total R&D funding and that share grew to a high point of 70 percent in 2000; the share then began to fall and, in 2003, industry provided only 63 percent of R&D funding. In the early 1990s, manufacturers provided almost 75 percent of the R&D funds provided by private industry and in 2003 the sector provided about 58 percent of those funds.

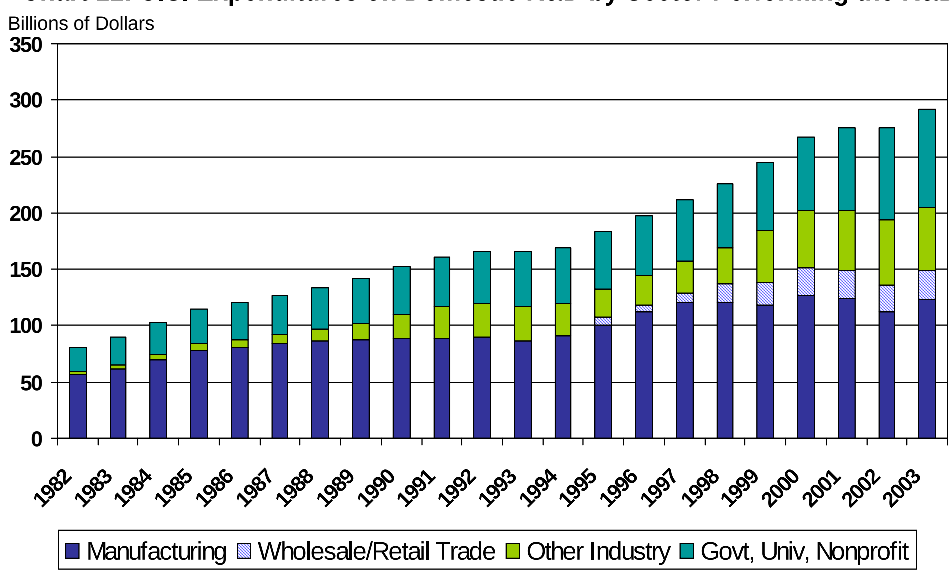
2001 reflected research done for the manufacturing part of those firms. Secondly, the publishing sector was removed from the manufacturing sector in 1999 because of the change to the NAICS based industrial classification. While publishing was not a major funder or performer of R&D, its removal from manufacturing does impact the manufacturing share by close to half a percentage point. The third factor is an increase in the amount of R&D done by specialized R&D companies that are classified in the business services sector of the economy. Many of those companies are providing their services to manufacturing businesses. Due to the method by which the statistics are generated, the funding for this R&D does not usually show up as coming from the manufacturing sector even though much of the work seems to be produced for the benefit of that sector.

[69] The latest data on federal R&D funding indicates that the share of total federal R&D expenditures that are spent on defense have increased from 54 percent in 2000 to 59 percent in 2005.

[70] "President's FY2006 Budget Requests Level R&D Funding," by Ronald Meeks, *Info Brief,* National Science Foundation, October 2005.

R&D funding suffered due to the recession with funding for domestic industrial R&D declining by four percent in 2002 before rebounding in 2003. However, industry funding for applied research in 2003 was still about nine percent below its 2000/2001 average, with funding for development now consuming a larger percentage of the total dollars. Even with a rebound in 2003, R&D funding has barely kept pace with inflation. In real terms, funds available for industry R&D have fallen by 1.6 percent per year during 2000-2003, largely due to a decline in the funding provided by the companies themselves.

Chart 11: U.S. Expenditures on Domestic R&D by Sector Performing the R&D



Source: National Science Foundation

JPC/ECS

A company's availability of funds for R&D depends on its sales and even more importantly on its cash flow. One measure of the cash flow available for such investments is the depreciation charges of a company plus the profits it retains rather than distributes as dividends to its shareholders.[71] The recession made a noticeable impact on

[71] In 1990-93, manufacturing (excluding publishing to make it more comparable to a NAICs definition) was paying out more than 26 percent of all corporate dividend payments to shareholders in addition to retaining enough earnings to fund its investment programs. Manufacturing's share of dividend payments declined to

this measure of corporate manufacturers' cash flow, it fell by 26 percent between 1999 and 2001. However, as the economy has improved so has cash flow. In 2003, it was 12 percent above the 2001 levels and there was a 15 percent improvement between 2003 and 2004. That indicates there is room in budgets to fund increased R&D. The increase in industry-funded R&D between 2002 and 2003 probably is an indicator of that improved cash flow.

One other potential brake on future R&D growth could be the competing demands on the cash flow of some of the largest investors in R&D in the United States — the automotive companies are an example.[72] NSF's statistics indicate that in 2003, motor vehicle manufacturers spent about 2.4 percent of sales on domestic R&D, down from 3.2 percent in 2000. While reported R&D increased slightly in 2004 among the traditional big three, only Ford spent more than it did in 2000.[73] The difficulties faced by those companies may have the effect of focusing R&D on the most productive possibilities and enhancing company productivity growth but sometimes those difficulties cause such wrenching change that the momentum for innovation is lost, at least temporarily.

Company-funded domestic R&D was about 3.7 percent of the sales of manufacturing companies conducting R&D in 2001. In 2003, that share had fallen to 3.1 percent.[74] The 2001 peak of intensity (R&D as a share of sales) reflects a combination of relatively strong R&D investment combined with some weakness in sales as economic growth slowed during the recession. The intensity of R&D varies considerably by industry and by size of firm. Computer and electronic products, the industry sector with the highest R&D intensity among the manufacturing industries, showed a peak R&D-to-sales ratio of more than 11 percent in 2001, dropping to eight percent in 2002 and

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19 percent of the total corporate dividend payments in 2001 but has improved to about 22 percent in 2004. Bureau of Economic Analysis, U.S. Department of Commerce.

[72] In 2003, motor vehicle R&D accounted for about 15 percent of total manufacturing R&D.

[73] Annual reports of GM, Ford, Daimler-Chrysler.

[74] "Company and other non-federal funds for industrial R&D as a percent of net sales of companies that performed industrial R&D in the United States," Table 27, National Science Foundation, December 2005.

rebounding to above nine percent in 2003.[75] Chemical companies and machinery manufacturers report spending four to six percent of sales on domestic R&D during 2000-2003. Medical equipment manufacturers have experienced a decline in intensity, investing 13 percent of sales in domestic R&D in 2000 but only six percent of sales in 2003.

Service sector R&D is increasing over time although perhaps not as much as is indicated by the official statistics since the majority of the R&D in the trade sector, considered part of services, is related to manufacturing production. The major focus of service sector R&D is in the computer software and computer system design areas. However, R&D performed by those two sectors was equal to only about 20 percent of the total performed by manufacturing in recent years. Consequently, it is not likely that service sector R&D will grow rapidly enough to offset significantly slower growth in manufacturing sector R&D.

The National Science Foundation's R&D statistics focus primarily on R&D performed in the United States. However, the recently released 2003 industry data provide some insights into the funding of R&D abroad by U.S. companies. Funds provided for foreign-performed R&D have grown by almost 73 percent between 1999 and 2003 with a 36 percent increase in the number of firms funding foreign R&D. Among manufacturing companies the increase in funding has been smaller, showing a 42 percent increase from $12.5 billion in 1999 to $17.8 billion in 2003. This increase in funding for foreign-performed R&D indicates that industry investment in R&D has not been quite as weak as indicated by the domestic numbers alone. Funds for industrial domestic R&D grew only one percent between 2000 and 2003 and funds for domestic manufacturing R&D fell by 2.5 percent during that time period. If funds for domestic and foreign-performed R&D are added together, total industrial R&D increased by six percent during the 2000 to 2003 time period and increased two percent for

[75] "Company and other non-federal funds for industrial R&D as a percent of net sales of companies that performed industrial R&D in the United States," Table 27, National Science Foundation, December 2005.

manufacturing. The combined total for manufacturing companies still declined in 2001 and 2002 but not as sharply as did their domestic R&D investment alone.

NSF data on R&D funding in 2004 are not yet available. A recent U.K. study that focused on R&D funded by the largest global firms has some encouraging information. The U.S. firms (in all industrial sectors) that fit into this category had increased their R&D spending by seven percent between 2003 and 2004. Among the U.S. firms with the largest R&D budgets, more were increasing their budgets than not. This study did not provide aggregate information by industry although it did indicate that U.S. firms were well represented in all the industrial sectors with the highest levels of R&D. However, because these firms tend to be multinational in nature, this does not provide information on how much of this R&D is being performed domestically.[76]

iii) The R&D Base and Inputs to the R&D Process

With the increase in globalization, firms in the United States are certain to perform some R&D abroad just as some foreign manufacturers do some of their R&D in the United States. However, any significant reduction in R&D not only threatens the spillovers discussed earlier but will impact the U.S.'s ability to maintain a viable base with which to do innovative, front-line research. As mentioned earlier, a recent article on innovation by Michael Orlando and Michael Verba identified the importance of "thick markets" for the inputs to innovation. While their argument focused on some of the advantages for having geographic centers for R&D within the United States, their reasoning also highlights the importance of maintaining a domestic R&D base in the United States: more populous places can support markets for the very specialized personnel and equipment that are needed for R&D, making them a more cost effective place for innovators to work. The authors make the further point that this is especially needed for new, "cutting-edge" innovations because such research is more likely to take unexpected turns requiring the acquisition of new and different inputs than were previously needed.

[76] "The 2005 R&D Scoreboard," United Kingdom Department of Trade and Industry, October 2005.

Such thick markets for the inputs to innovative activities also require replenishment and growth of the types of inputs needed for R&D. One of the most important of those is trained personnel. The United States is not keeping up with other countries in that area. That weakens the concentration of inputs needed for R&D, if it is to be performed in the U.S. At the same time, other countries are building their own markets for such innovative inputs and creating an improved atmosphere in which to foster R&D.

Science and engineering have never been the top fields of choice among American college students. The latest statistics available show that in 2003, the United States awarded 1.3 million bachelor's degrees. Of those, about 13 percent were in the physical, biological, agricultural or natural resource sciences, almost six percent were in engineering, about four percent in computer and information science and less than one percent were in mathematics. Bachelor's degrees in these fields accounted for approximately one-quarter of the total. The distribution of the 512,000 master's degrees awarded was very similar.

The percentage of doctoral degrees awarded in the science and engineering fields is higher, almost 45 percent of the 46,000 doctoral degrees awarded in 2003 were in these areas. [77] In addition to the newly minted graduates in these fields, the United States depends on a significant number of foreign-born professionals to fill in the ranks of its scientific and engineering workforce. In 2004, about 17 percent of the professional workers in the computer, math, engineering, and life and social science fields were foreign born.[78] The percent of foreign-born workers among doctoral degree holders in the U.S. science and engineering workforce approaches 30 percent.[79]

Manufacturing is heavily dependent on these skilled workers to perform its R&D. In January 2004, manufacturers employed 56 percent of all full-time equivalent scientists

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[77] *Digest of Education Statistics, 2004*, U.S. Department of Education, Tables 250-252.

[78] "Labor Force Characteristics of Foreign Born Workers in 2004," Bureau of Labor Statistics, May 12, 2005.

[79] *Science and Engineering Indicators, 2004*, National Science Foundation, May 2004.

and engineers performing industrial R&D in the United States.[80] That is down from 59 percent at the beginning of 2001 but indicates a heavy dependence on this workforce to maintain a viable U.S. R&D base. A positive sign for continuing strength in the domestic R&D base is the nine percent increase between 2003 and 2004 in full-time equivalent science and engineering personnel working in manufacturing.

However, the recent trends in the number of advanced degrees provide an unsettling picture for the future of this skilled sector of the American workforce. The number of U.S. doctoral degrees awarded in the fields of science and engineering has fallen five percent between the mid 1990s and 2004. Doctoral degrees in engineering have fallen eight percent during this time period although there has been some improvement since their 2002 low point. Those numbers, however, do not show the full impact on the pool of labor for U.S. R&D positions. The decline between 1996-2003 in doctoral degrees awarded to U.S. citizens or permanent residents has been much larger, almost 20 percent for total science and engineering degrees and more than 35 percent for engineering degrees alone. At the same time, the number of foreign students with temporary visas that have obtained such degrees has grown by more than 10 percent. In fact, since 2001, more engineering doctorates have been awarded to students with temporary visas than were awarded to U.S. citizens and permanent residents. While students with temporary visas may not be lost to the U.S. workforce, there is certainly an increased chance that those students will choose to return to their home countries to apply their knowledge. In recent years, another factor has also played a part in reducing the number of foreign students that come to the United States to study; increased security concerns and a tightened visa process makes it harder for students to enter the United States in a timely fashion. U.S. universities are the most likely source of foreign-born professionals to fill in the ranks of the science and engineering workforce, if those students are less likely to come to the United States for their training, maintaining the strength and vitality of its trained scientific workforce faces another hurdle.

[80] "Full-time equivalent R&D scients and engineers in companies that performed industrial R&D in the United States," Table 41, National Science Foundation, December 2005.

Serving students that cannot or do not choose to come to the United States has led to new opportunities for U.S. service exporters. There is a big global market in higher education and training services. As one analyst has observed, "[s]ome [U.S. colleges and universities] are setting up shop overseas to serve local populations, either because they sense an opportunity, or because they've been invited by a host country in need of more education options. Still, it's hard to get a handle on how many schools have overseas branch campuses because even accrediting bodies don't track those numbers."[81] Many schools have newly located or expanded their educational services into overseas markets, partly because industrializing countries view higher education for their populations as an important step in the process.[82] While this may be an opportunity for U.S. service exporters, it does not increase the skilled workforce of the United States since after receiving their training most of these students will not enter the U.S. labor pool.

China and India are rapidly increasing their training of students in the science and engineering fields and they are becoming the primary world suppliers of scientists and engineers to a growing global marketplace.[83] China had about 1.3 million graduates from institutions of higher education in 2002, slightly less than the United States. But, of those, 50 percent earned degrees in the sciences, engineering or medicine. The single most frequently awarded degree was in engineering, 34 percent of the total. Furthermore, the number of engineering graduates increased from less than 350,000 in 2001 to more than 640,000 in 2003. In addition to dramatically increasing college enrollments, China is also focusing on transforming its top universities to world-class institutions with a focus on science and technology. A recent article in *The New York Times* quotes China's second-ranking official, Wu Bagguo, on this subject. "First-class universities increasingly reflect a nation's overall power." And, China's "model is simple: Recruit top foreign-trained

[81] "Going Global U.S. Colleges and Universities Head to Distant Lands, and Approach the Challenge in Remarkable Different Ways," by Elizabeth Gardner, *University Business*, October 2003.

[82] It should be noted that many job opportunities associated with U.S. teaching and research facilities are likely filled from the local labor market.

[83] "The Changing Dynamics of the Global Market for the Highly Skilled," by Andrew Wyckoff and Martin Schaaper, OECD, paper prepared for the National Academy of Science's *Advancing Knowledge and the Knowledge-Economy Conference*, January 2005.

Chinese and Chinese-American specialists, set them up in well-equipped labs, surround them with the brightest students and give them tremendous leeway. In a minority of cases, they receive American-style pay; in others, they are lured by the cost of living, generous housing and the laboratories." [84] According to *Fortune* magazine's estimates, in 2005, the United States graduated 70,000 engineers, compared with 600,000 for China, and 350,000 for India.[85] In addition, 20 to 30 percent of the students graduating with a bachelor's degree in Taiwan, South Korea and Japan received engineering degrees.[86]

The lower labor costs in China and India are attracting the establishment by multi-national companies of research facilities abroad using indigenous scientists. Some point to the possibility that R&D will be conducted in cyberspace. But the question is what kind of R&D and will it be able to generate the spillover potential provided by the kind of proximity described earlier.

In fact, concerns about maintaining a viable R&D base and its needed inputs are prevalent in many of the industrialized countries. Despite turning out almost 20 percent of its graduates as engineers, Japan has been changing its laws and policies to better compete for foreign skilled workers in these areas. In 2001, the OECD reported that the R&D expenditures of China, Israel and Russia equaled 15 percent of spending by the OECD countries on R&D, up from only 6.4 percent in 1995.[87] At its March 2002 meeting in Barcelona, the European Council reacted by establishing a target of three percent of GDP for R&D spending by 2010. Britain instituted a new R&D tax credit in 2004 in support of its goal of increasing R&D to 2.5 percent of GDP by 2014. A recent survey by the Confederation of British Industry (CBI) on the results of the credit indicated it reduced costs by about four percent although the original target reduction was for a 10 percent reduction in costs.[88]

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[84] "China Luring Scholars to Make Universities Great," by Howard French, *The New York Times,* October 28, 2005.

[85] "America Isn't Ready," by Geoffrey Colvin, *Fortune,* July 25, 2005, p. 72.

[86] *Science and Engineering Indicators, 2002,* National Science Foundation.

[87] *OECD Science, Technology and Industry Outlook 2004,* OECD, 2004, p. 12.

[88] "R&D Tax Credits Progressive with Incentives for R&D," *Business Voice,* CBI, www.cbi.org.uk.

The United States has also encouraged R&D expenditures through tax credits although those credits expired at the end of 2005.[89] A recent study by NSF examined the use of research and experimentation (R&E) tax credits. In 2001 (the latest year available) $6.4 billion of R&E tax credits were claimed — down slightly from the $7.1 billion claimed in 2000.[90] Of that amount about $4.2 billion went to manufacturing firms. However, that amount is only about three percent of all manufacturing R&D in 2001, a result that is somewhat lower than the British experience.

Maintaining a strong R&D base and its ability to innovate is the foundation for one of the more important U.S. service exports — payments for using a U.S. patent or other form of intellectual property. In 2004, those payments made up about 15 percent of service exports.[91] Almost 75 percent of the payments for intellectual property are between affiliated companies — U.S. firms and companies they own or controls overseas. While this share has declined slightly since the mid 1980s, such payments are one indication of the internationalization of U.S. manufacturing know-how. However, the allocation of patents in the United States provides further information on the processes of innovation in the goods-producing industries and of increased globalization. The majority of patents granted in the United States are granted to U.S. citizens or companies. But in 2004, 48 percent of all patents went to foreigners compared to 43 percent in 1994. The number of utility patents granted to U.S. entities has shown little growth since 1999 and declined by about four percent between 2003 and 2004. Grants of utility patents to foreign owners also declined by about one percent between 2003 and 2004, but grew at an average annual rate of about four percent in the preceding four years.[92] Of the 10

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[89] As of mid January 2006, they had not been reinstituted although Congress was considering a one-year extension of the credits.

[90] "The U.S. Research and Experimentation Tax Credit in the 1990s," by Francisco Moris, *Info Brief*, National Science Foundation, July 2005.

[91] BEA data also show that about eight percent of service imports are for U.S. expenditures to license foreign intellectual property.

[92] "U.S. Patent Statistics, Calendar Years 1963-2004," U.S. Patent and Trademark Office, May 2005.

companies that received the most U.S. patents in 2004, only four were U.S. companies. The others were Japanese or Korean owned.[93]

VII. Significant Consequences if Recent Trends Continue

Three main inputs are used to create a nation's wealth. The first input is a nation's stock of knowledge. R&D is the major ingredient for the growth of that knowledge. The second is its stock of tangible, physical assets such as structures and equipment. The third is its human capital — the nation's labor force and its level of training and education. Productivity links those inputs to output. Changes in the quantity of each input used and in its productivity determine the level of output.

Manufacturing is a major producer and user of each of these three endowments. It creates knowledge by performing close to one-half of U.S. R&D. And it uses the R&D to create new products and productivity-raising processes. Its strong productivity performance significantly increases the output potential of the country.

Manufacturing also produces and uses physical assets. Its ability to innovate and incorporate new ideas into manufactured equipment provides productivity gains to the workers in all the industries that use them. Manufacturers, as one of the major purchasers of equipment, are one of the major beneficiaries of those productivity gains. Since the end of the recession, labor productivity in manufacturing has grown at an annual rate of 5.5 percent per year, a major contributor to the 3.3 percent pace for the non-farm economy overall. This performance is the key basis of the U.S. competitiveness with other countries. Those improved, cost-competitive goods are sought by others and drive increases in U.S. high-tech exports.

Last but not least, manufacturing provides job opportunities for two major components of the U.S. labor supply — production workers and scientists and engineers. It provides good wages and training to production workers and can foster stimulating work environments for its scientists. By this process, manufacturing has added to the

[93] "Patenting by Organization, 2004," U.S. Patent and Trademark Office, p. B1-1.

nation's stock of human capital. Lately, the United States has not been building human capital as quickly as it once did.[94] One of the worrisome aspects of that trend is that the quality of our primary education has slipped relative to other countries and that gives our students a poor base on which to build the highly proficient and skilled labor force the United States will need.

In the previous section, recent trends in R&D, capital investment and labor demand were presented. In this section, the risks to the U.S. economy posed by developments in these three areas are discussed.

A. R&D and Innovation Are Threatened

In his book, *The Free-Market Innovation Machine,* William Baumol discusses the "three critical features of innovation that can, so to speak, magnify the contribution of technical change to the economy's GDP."[95] Those are: 1) the cumulative character of many innovations — called innovation breeding, where one new idea suggests another new idea; 2) the public-good property of innovation — often thought of as a spillover effect; and 3) the accelerator feature of innovation — the process whereby innovation produces productivity gains that allow the economy to grow at a faster pace. His analysis leads to the conclusion that any decline in innovation bodes ill for the continued growth of the U.S. economy. Weakening R&D investment and/or a lack of skilled R&D workers would threaten the pace of innovation in the United States.

As discussed earlier, service sector R&D is unlikely to grow quickly enough to supplant manufacturing sector R&D partly because there are only a few areas of the service sector that are conducive to the types of R&D that drive major, economy-wide changes. The R&D intensity of services overall is relatively low because only a few sectors invest heavily. The intensity of R&D in the sectors that do extensive R&D, such as software, tend to be as high as it is in the sectors of manufacturing that are heavily focused on R&D, as much as 15-20 percent of sales in some years. However, large

[94] "America Isn't Ready: Here's What to Do About It," by Geoffrey Colvin, *Fortune,* July 25, 2005, p. 72.

[95] *The Free-Market Innovation Machine,* by William Baumol, Princeton University Press, 2002, p. 51.

service sectors such as construction, finance, utilities and broadcasting spend less than 1.5 percent of sales on R&D. Further, as the OECD points out, service sector firms tend to be licensees of innovation rather than producers.[96]

Industrialization and a growing overseas manufacturing base are providing other global centers with the critical mass necessary to promote R&D growth. At the same time, the challenges faced by the U.S. manufacturing base, the traditional center of R&D strength, threatens to reduce the mass critical for the continued innovation process here in the United States. If concentrated centers of R&D are lost, the spillovers and growth derived from that innovative activity is lost. As this happens, a decline in the U.S. long-term economic growth rate is all but assured.

Manufacturers' decisions to invest in R&D in the United States require a positive outlook about the industry. If the outlook is an encouraging one, the next issue is the availability of funding. The ability to fund new R&D spending comes largely from the profits that a company can plow back into its business. Thus, the available cash flow of manufacturing firms is closely linked to their ability to perform R&D work as well as make capital investments. Cash flow is driven by profits and depreciation charges. While manufacturing profits are cyclical, they are strengthened by strong productivity, a necessary ingredient. Depreciation charges are more stable over time but can be influenced by tax policy.

Two other factors, longer term in nature, also temper private R&D spending. The first is the inability of producers to recover the fruits of all of their spending through the prices they charge for their innovations.[97] It is widely agreed that firms doing R&D do not capture all or even most of their investment through the price mechanism. The existence of these essentially "free" spillovers means the social return from R&D exceeds the private return. That can lead to reluctance by firms to undertake some higher risk projects. The second circumstance of social returns being greater than private returns is related to the scope of the benefits from R&D. A single firm is unlikely to use the full

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[96] *OECD Science, Technology and Industry Outlook*, OECD, page 15.

[97] "The Search for R&D Spillovers," Zvi Griliches, NBER Working Paper No. 3768, July 1991.

scope of possibilities from innovations resulting from its R&D. This may be increasingly true as firms focus on producing results from their R&D that will primarily benefit their core businesses.

A recent Booz, Allen, Hamilton study posits that while a company can suffer from too little R&D it may also be possible for it to spend too much on R&D. "These findings seem to suggest that at any given time there's only so much research that a company can nurture and commercialize. Beyond that, the company provides a public service — value to society perhaps, but not to its shareholders."[98] While this philosophy promotes businesses using the best practices to make the most productive use of their R&D budgets, it could also result in a reduction of positive spillovers from R&D.

In both the United States and other OECD countries government policies encourage R&D through direct funding of research and indirectly — largely through tax credits. Such tax relief is not only helpful but justifiable in recognition of the instances described above where social returns to R&D are higher than the private returns. While the amount of the tax credits that companies receive has been a very small part of their total cost of R&D, the credits should be continued to generate the broader social gains produced from the spillover effects of R&D.

B._Capital Investment, the Multiplier and Economic Growth Weaken

As noted earlier, every dollar of manufacturing production for final sales stimulates an additional $1.37 in output once its impact has pervaded the economy. Manufacturing creates and consumes capital goods. It is a capital-intensive industry, as reflected by its high capital-to-labor ratio. Thus manufacturing has a positive effect on economic growth through the demand for intermediate goods and on final demand for capital investment.

If the manufacturing share of output contracts, other things equal, its contribution to overall national stimulus will diminish. It also would cause the U.S. economy as a

[98] "The Booz Allen Hamilton Global Innovation 1000: Money Isn't Everything," by Barry Juaruzelski, Kevin Dehoff and Rakesh, Bordia, *Strategy + Business*, Winter 2005, p. 9.

whole to become less capital intensive. Since capital deepening is an important source of labor productivity, that would have negative consequences for productivity gains. There are two ways such a loss could be offset: One is if manufacturing increases its capital intensity — the amount of capital it uses per unit of output — or the service sector makes up the slack by growing faster and/or increasing the capital intensity of its own production. Clearly those processes will offset the effect of the decline in manufacturer's share of output, but the extent of the offset is problematic. Thus any contraction in the manufacturing share of GDP can not be taken lightly.

C. Well-Paying Jobs Will Continue To Be Lost

Manufacturing jobs are always lost during recessions. However, during past recoveries, the number of jobs has generally grown. As Chart 8 showed, this expansion has not been like any other expansion. Job losses in manufacturing have continued and more downsizing has been announced by manufacturing firms. While the stellar productivity growth in manufacturing has partially offset that impact on the economy, it has still caused a painful readjustment in the structure of the U.S. labor force.

One aspect of this rapid decline in manufacturing employment is the focus by manufacturers on core businesses. Business units outside those core areas of competence are spun off or closed, some become separate domestic firms (not all of them in the manufacturing sector) and others move to foreign locations, or the work is outsourced to a foreign firm.[99] This "hollowing out" of industry can have significant impacts beyond the job losses. The movement overseas of manufacturers affects the entire industrial network. As manufacturers relocate overseas, suppliers all the way up the supply chain must evaluate such options as well.

[99] The number of jobs literally moved overseas by U.S. manufacturers appears to be small. BEA's data on multinational companies show that employment by manufacturing parent firms has declined by about 480,000 or 6 percent between 2001 and 2003. However, employment of those firms' majority-owned affiliates has declined as well, by about 48,000 or one percent. Employment in majority-owned affiliates in China and Hong Kong have increased by about 38,000 but at the same time employment in India, the rest of Asia and Latin America has declined. The data only measure the employment in affiliates of the U.S parent and do not measure employment changes that take place by contracting the work to a non-affiliated entity.

This should be of concern to those who argue that good non-production jobs will replace lost manufacturing jobs. An alternative (and more plausible) scenario is that the resulting change in job mix will result in a lower overall real wage level for U.S. workers. The data discussed earlier, on the lowered wages of re-employed displaced workers across all industries, point in that direction.

D. The Challenge to the U.S. Economy

Figure 1 (page 4) depicts the innovation process and how a vibrant domestic manufacturing sector makes its significant contributions to U.S. growth and standard of living. The chain of adverse results from a contraction of the manufacturing sector starts with a reduction in R&D spending. Since service R&D is not structured to pick up the slack, total R&D declines, which it has already begun to do when measured in real terms. Such weakness would also reduce the number of spillovers that generate their own innovative activities.

The decline in the pace or absolute level of U.S. innovation weakens a major driver of the U.S. economy — capital spending — which itself is driven by innovation. Not only would that put productivity growth at risk but the production of capital goods would increasingly shift abroad, creating greater incentive for expanded R&D spending there. At a minimum, the extent of U.S. leadership in innovation will diminish as ever more countries devote a larger share of their GDP to such spending.

Any contraction of the manufacturing base will also impact the U.S. labor market structure. Well-paid manufacturing jobs, as well as even better paid jobs in science and engineering will be harder to find. That will decrease the education and training manufacturers conduct for their production workforce. It will serve as an inducement for more foreign-born, U.S.-educated science and engineering students to return to their home countries and prompt some of our engineers and scientists to seek employment abroad, particularly in countries where English speakers are in short supply.

This scenario, a quite credible one in our view, describes perhaps the most daunting challenge to the U.S. economy and U.S. economic policy we have yet encountered. Yet, to the extent that there is a parallel between current global competition and conditions of the early 20th century there could be a cause for some optimism. Then a progressive economic policy staunched some of the fears and laid the groundwork for our successes later in that century.[100]

VIII. Conclusions — Promote U.S. Production

The issues addressed in the paper concern economic growth, investment, exports, productivity, research and development, and well-paying jobs. All are related because they are "production" driven. Higher and faster growing U.S. production would impact all of these areas of concern in a positive way. If the United States is to have an economic policy, it should be one that focuses on and stimulates those factors that will make U.S.-based production a viable and profitable business choice.

Currently the U.S. economy and economic policy are consumption oriented. That stance is justified, not incorrectly, on the role of consumption in stimulating production. But there is growing realization that the production so stimulated will not necessarily take place in the United States. Thus the emphasis of U.S. policy must be placed directly on accelerating production here. This emphasis should induce the productivity-enhancing investment essential to increasing competitiveness and raising the U.S. standard of living.

That emphasis will not hurt consumption because the cause and effect goes in both directions. Our argument here is simply that it will be more effective to emphasize stimulating consumption through production rather than the other way around. This difference on emphasis is vital.

Many readers may ask if this emphasis on production is not merely another way to pose the need for saving and investment. If so, why not emphasize saving? The reason is that the relationship between savings/investment and production is translucent at best.

[100] "The Era To Bring Back," by Joel Kotkin, *The Washington Post*, October 9, 2005, p. B1.

And, because of their nature, savings and investment policies do not assure production here in the United States if other factors that directly support U.S.-based production are not in place.

The elevation of the banner “U.S. Production” as the objective of our economic policy puts the emphasis where it is needed. Many pro-production policies, perhaps the most effective ones, do not require agreement with foreign countries to take effect. There is a wide scope for unilateral action by the United States. Pro-production policy need not be implemented by reversing any policies beneficial to consumption, investment and saving. Successful pro-production policies will cause consumption, savings and investment activity to fall into place as well.

Promoting production here need not restrict U.S. direct investment broad. Producing abroad has clear advantages for some products, for some services, for some markets and for some host countries. The emphasis on U.S. production should focus on the margin at which the United States could be competitive and on insuring a thorough consideration by U.S. and foreign firms of investments here and on the development of new products uniquely appropriate for U.S. production. The United States cannot become complacent based on its historic central role in the world economy. All of its economic players must be at the top of their game to maintain the U.S. standard of living.

What types of policies promise the most direct positive impacts on the innovative process and the U.S. production that drives that process?

- U.S. manufacturers’ productivity growth is enviable. It must remain so. But productivity growth depends on investment in knowledge and investment in equipment that embodies new innovations.

- Along with increasing efforts to improve K-12 education, a special emphasis should be placed on improving the quality and rigor of math and science offerings at all levels. The problem-solving and critical-thinking skills those subjects teach will be vital for the U.S. workforce to compete in a global economy.

- Support continued R&D investment by industry by renewing the R&D tax credit. Increase Federal spending on basic research with a focus on specific areas where social and private returns look most promising. Encourage and continue to fund basic research by colleges and universities and the spillovers that come from such research. But the “D” in R&D — largely product and process development — should be emphasized as well. Promote innovation clusters needed to spur such developments, to encourage thick markets for R&D inputs and to increase the productivity of each dollar of R&D spending.

- “U.S. Production” should encourage workers to continuously pursue education and lifetime training so that they are more adaptable to improvements from innovation and to potential structural changes. New labor force entrants should be encouraged to take up the skilled jobs in which shortages are emerging and top engineering and scientific talent should be nurtured.

- Focus on elimination of those workforce, investment and policy obstacles to domestic production and competitiveness that would provide the greatest economic return.

- Encourage the improvement of the efficiency and speed of the U.S. transportation and communication infrastructures.

- Improve tax and intellectual property laws and infrastructure needed to leverage investment in research and development by enhancing the environment for spillovers without needlessly facilitating technology transfers.

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