



Manufacturing Resurgence

A Must for U.S. Prosperity

A Study by Joel Popkin and Kathryn Kobe

January 2010

Prepared by Joel Popkin and Company for
the National Association of Manufacturers and the NAM Council of Manufacturing Associations

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Industrial Truck Association
Institute of Scrap Recycling Industries
International Sign Association
Metals Service Center Institute
National Marine Manufacturers Association
National Shooting Sports Foundation
NEMA—The Association of Electrical and Medical Imaging
Equipment Manufacturers
NPES
Non-Ferrous Founders' Society
Plumbing Manufacturers Institute
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Soap and Detergent Association
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David Asselin
Vice President & Executive Director
NAM Council of Manufacturing Associations

Executive Summary

This report presents the reasons to revitalize the United States manufacturing base and formulates recommendations for achieving that goal.

It rests on three fairly obvious facts:

1. An increment to manufacturing production in the U.S. creates more economic activity both within and outside the sector than does a similar increment in any other major sector.
2. Manufacturing industries perform almost two-third's of private sector R&D and have the highest R&D intensity, as a percent of sales, of any major industrial sector.
3. Historically, manufacturing's innovations and investment raised its productivity faster than other large sectors and its productivity has added substantially to overall U.S. productivity.

This report follows two earlier ones highlighting manufacturing's contributions to the U.S. economy. The last report called attention to five warning signals that these benefits are at risk.¹ Some of those warning signals have become more evident as the U.S. economy has weathered a severe recession, none has ameliorated. Now is a propitious, if not the last, time to act decisively to address the issues that prompt these warnings. That is because policy-makers are increasingly recognizing that a strong, efficient and innovative U.S. manufacturing base is essential to our country's economic future in a competitive world environment.

There are a number of reasons for this recognition, but the starkest is the U.S.' large trade deficit. U.S. consumers and businesses consumed manufactured goods valued at \$5.8 trillion dollars in 2008. In addition to the \$4.3 trillion worth of goods that U.S. manufacturers produced for the domestic market in 2008, they also produced \$912 billion worth of manufactured goods that were exported to other countries. Those exports helped pay for somewhat more than half of the \$1.5 trillion of manufactured imports that U.S. consumers and producers consumed. However, since

total goods and services exports were still inadequate to pay for all U.S. imports, indebtedness to foreign countries, particularly China, continued to rise.²

The report that follows addresses this and other U.S. economic developments stemming from a weakened manufacturing sector. It identifies the underlying issues and presents a framework for U.S. economic policy and specific recommendations within that theme. The fundamental concept used to select policy options remains the same as those recommended earlier:

- Emphasize policies that accelerate and strengthen manufacturing production here in the U.S.; in particular, encourage investments (private and public) that enhance productivity, such as those in R&D, capital goods, worker training, and early education that nurtures math and science proficiency.

Specific recommendations, consistent with these fundamental focuses include:

- Reduce the corporate income tax rate on profits earned from production in the U.S. to match those of our major trading partners.
- Eliminate one important uncertainty in private decisions to undertake R&D by making the R&D tax credit permanent.
- The National Science Foundation should hasten its efforts to identify the most promising areas for basic R&D so that companies can increase the share of such research they undertake.
- Make the commitments now that will guide private decisions on R&D investment for cleaner energy technologies and more varied energy sources. Findings from that research will help mitigate energy price spikes and make domestic manufacturing production more attractive to both U.S. firms and foreign investors.

¹ *U.S. Manufacturing Innovation at Risk*, Joel Popkin and Kathryn Kobe, Council of Manufacturing Associations and The Manufacturing Institute, February 2006.

² In its most recent report, the Treasury Department reported that China held \$1.1 trillion of U.S. long-term debt in June 2008 compared with \$91 billion in 2000. *Report on Foreign Holdings of U.S. Securities*, U.S. Department of Treasury, April 2009, Table 28. Overall foreign holdings of U.S. long-term debt have increased from \$1.8 trillion in 2000 to \$6.5 trillion in 2008. (Table 1)

- Assure the health of small businesses. They are niche suppliers of components and parts for finished goods manufacturers. And they are also important investors in, and initiators of, high-risk, ground-breaking innovative endeavors.
- Governments at all levels should make investments in infrastructure and facilitate its expansion to encourage the R&D, production and academic clustering that maximizes spillovers and increases the public and private returns to R&D investment.

The groundwork for these and other recommendations, in greater specificity, are found throughout the report and presented in its final section.

U.S. manufacturers continue to step-up and meet the challenges resulting from cyclical downturn and structural readjustment. Their efforts are beginning to show some successes. But to remain strong players in a competitive world will require continued focus on innovation and productivity gains helped along by government policies that will smooth the path to success. This report hopes to be helpful in lifting the curtain on a resurgence of U.S. production that will bring with it the fruits of a higher standard of living for all Americans.

I. Introduction

Because of their dynamic nature, manufacturing industries are often characterized as engines of growth. Manufacturing can claim this calling for three reasons:

1. An increment to manufacturing production creates more economic activity both within and outside the sector than does a similar increment in any other major sector because of manufacturing's high multiplier effect and its extensive linkages to other parts of the economy.
2. Incremental growth in the sector is likely to increase U.S. R&D activity by more than a like-size increase in any other major private industrial sector because of the high intensity of innovation in manufacturing.
3. R&D, through the innovation process, boosts overall U.S. productivity growth, the source of improvements in its standard-of-living.

This report, the third by JPC for NAM, will support these points both by drawing on analysis and conclusions reached in the two previous studies (2003 and 2006) and by presenting new information. But the basic conclusion of this report is the same as its predecessors: America's manufacturing innovation process is vital to promoting economic growth, productivity gains and increases in our standard of living. At the

end of the 2006 report, a potential scenario was described whereby innovation declined, manufacturing contracted and the U.S. economy suffered losses of good jobs and found further improvements in its standard of living endangered. That scenario may well be playing out now, triggered by circumstances that were not foreseen at that time.

The data and analysis presented in this report clearly indicate the need for policies that promote U.S. production and innovation and that these objectives are best served by strategies that restore the health and the competitiveness

of U.S. manufactured products both domestically and in foreign commerce.

This report is coincident with a period of unusually weak worldwide economic activity not seen since the Great Depression during the early 1930s. The U.S. has been forced to make difficult decisions related to industrial policy. Other nations are also introducing policies to alleviate this economic stress and prevent its recurrence. By a combination of the recession's impacts and these actions, the world's industrial landscape will emerge changed. The direction of such change will be shaped by both the recovery from the current recession and the kinds of policies adopted so far and those that could be implemented as the policy process proceeds.

This report consists of seven sections. Following this introduction, Section II will discuss the current state of

America's manufacturing innovation process is vital to promoting economic growth, productivity gains and increases in our standard of living.

manufacturing and how things have changed since the last report was completed in 2006. Section III reminds the reader of the unique factors, discussed more fully in the first two reports, that make manufactur-

ing so important to the U.S. economy. Sections IV and V present new data and analysis on manufacturing's important contributions to R&D and productivity growth in the economy. Section VI paints the potential future face of manufacturing, and Section VII draws conclusions and presents policy recommendations.

II. What Has Changed — The Current State of U.S. Manufacturing

U.S. households and businesses consumed manufactured goods valued at \$5.8 trillion dollars in 2008, a 2 percent increase from 2006. A quarter of that amount, \$1.5 trillion, was imported and three-quarters, \$4.3 trillion worth of goods, was produced by U.S. manufacturers for the domestic market. U.S. manufacturers also

produced \$912 billion worth of goods that were exported to other countries, an increase of 16 percent since 2006. Clearly, manufacturing is still a vital part of the U.S. economy.

Since the 2006 report, the state of U.S. manufacturing has seen some bright spots and some dire omens. First, the bright spots:

1. The restructuring of manufacturing has intensified, generating a quantum improvement in the sector's ability to compete.
2. The sector has experienced a reduction in its competitive disadvantage according to an update of a trade-weighted structural cost study conducted by MAPI.³
3. Higher paying manufacturing jobs have increased as a percent of total sector jobs.
4. Manufacturing experienced a 19 percent increase in foreign direct investment in 2008 to \$141.1 billion, indicating the U.S. manufacturing base and the domestic market it serves remains attractive to foreign investors.⁴

But, some developments have now reached the critical point:

1. According to the Commerce Department, manufacturing's value-added contribution to GDP fell in 2008 to 11.5 percent and the unemployment rate in manufacturing exceeds 12 percent.
2. U.S. manufacturing labor productivity has declined during this recession and its pace of investment

in plant and equipment is lagging the rest of the economy.

3. The U.S. share of world R&D spending has fallen as a percent of total world R&D and the recession has damaged some of the key manufacturing industries that perform R&D, which may reduce their rate of R&D spending.
4. The U.S. financial sector has been crippled. It was viewed as the best candidate to provide growing service exports needed to offset the trade deficit in goods; this leaves the United States even more dependent on increasing manufactured exports in order to buy the imports the economy needs.

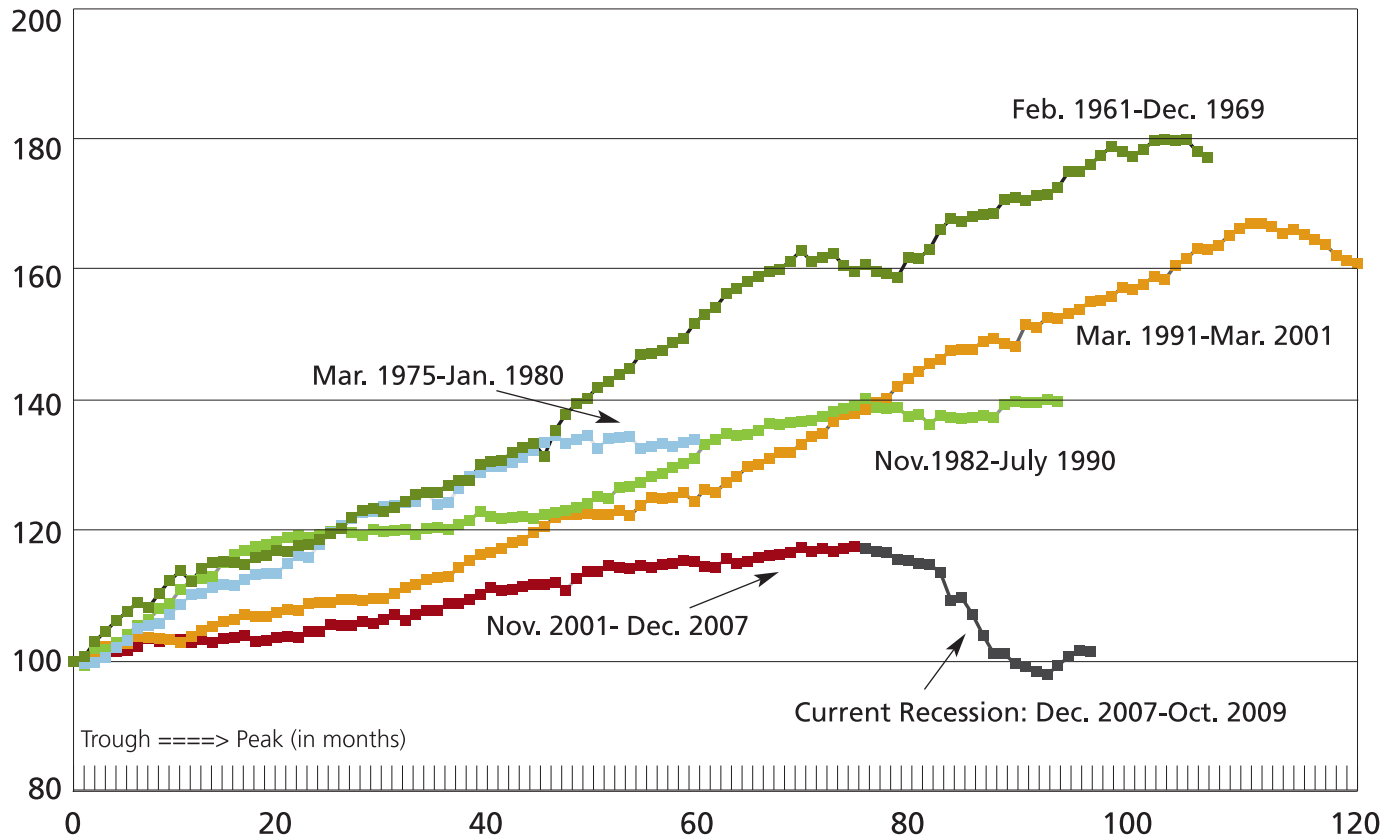
A. Growth, Capacity and Utilization

As is clear from the two earlier reports, manufacturing entered the current recession on an already sobering note. As Chart 1 shows, U.S. manufacturing has been expanding less vigorously in each of the five major economic expansions of the past 50 years. From the economy's trough in November 2001 to its business cycle peak in December 2007, manufacturing output grew at an annual rate of just 2.7 percent. That compares with an average annual rate of 5.2 percent for the other time periods in the chart and is well below the 7.6 percent rate forty years ago. Furthermore, the decline in manufacturing production since the start of the recession in December 2007 wiped out all the gains made during the most recent expansion. At its

³ *The Tide is Turning, An Update on Structural Cost Pressures Facing U.S. Manufacturers*, Jeremy A. Leonard, Manufacturers Alliance/MAPI and the Manufacturing Institute, November 2008. The sharp reduction in U.S. manufacturing's cost disadvantage reflected narrowing in differentials for employee benefits, pollution abatement and tort costs which more than offset a widening differential in the corporate taxation disadvantage since 2003.

⁴ Moreover, the Organization for International Investment estimates there were nearly 875 greenfield projects or expansions announced or opened in 2008. That is the largest number of planned greenfield projects by foreign companies since 2004. The advantage of greenfield projects is that they represent entirely new facilities and jobs rather than mergers or joint ventures with current companies. *The Impact on the U.S. Economy of Greenfield Projects by U.S. Subsidiaries of Foreign Companies, Top Projects for 2008*, Organization for International Investment, March 2009.

Chart I. 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.

JPC/ECS

lowest point in June 2009, manufacturing output was down 16.7 percent from December 2007.

Manufacturing capacity reached its peak in November 2008, up 7.1 percent from November 2001, when the expansion began. Capacity fell 1.0 percent between November 2008 and October 2009, with the largest declines in crude and semi-finished capacity. By June 2009, utilization of manufacturing capacity had reached an all time low of 65.2 percent. That compares to a low point of 70.9 during the 2001 recession. While investment in manufacturing structures has continued to show growth during the past year, primarily that is a reflection of refinery upgrades and some other long-term expansions that are close to being finished or being scaled back. The low rate of capacity utilization will reduce plans for future investment and slow the contribution of non-residential investment activity to GDP growth.

B. Competitive Position

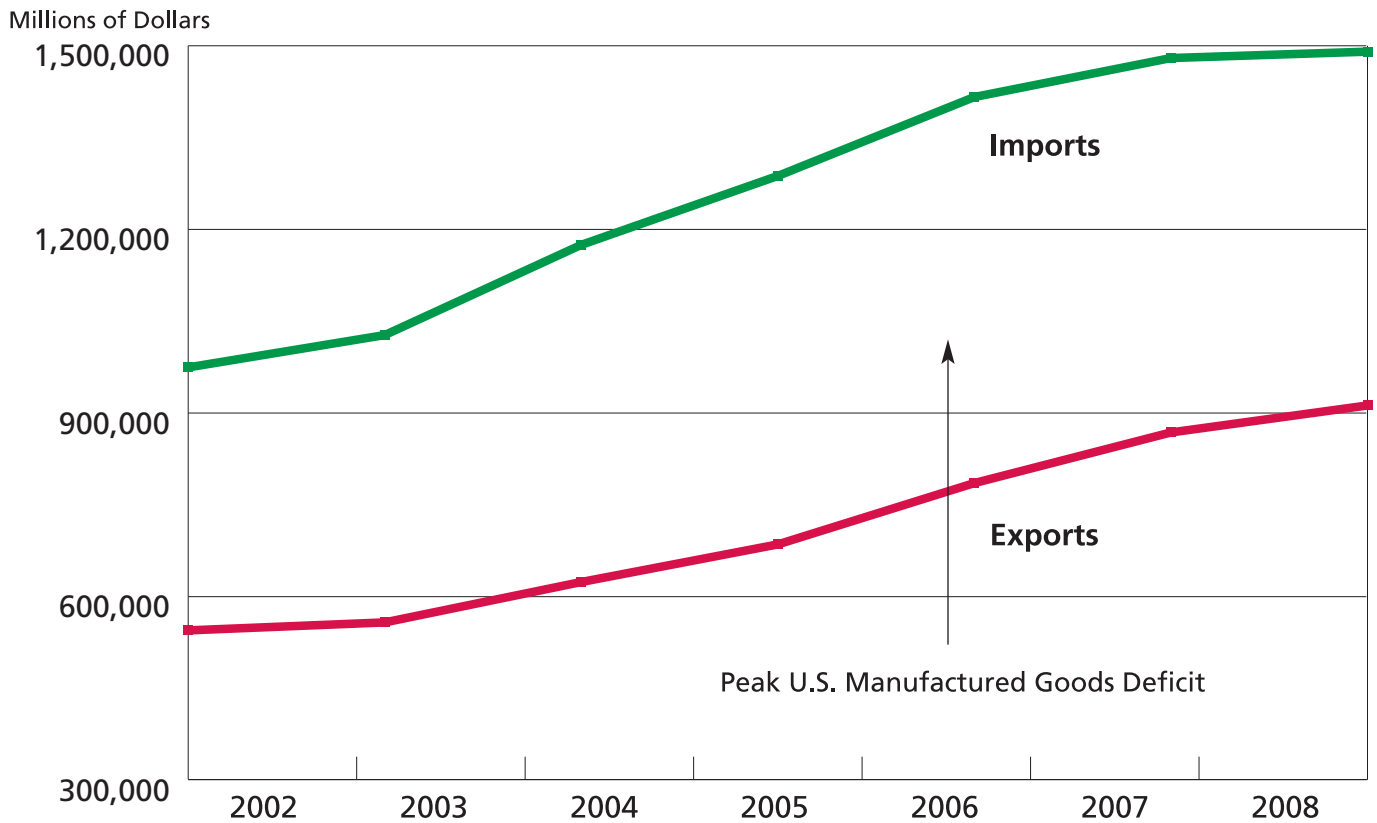
The U.S. competitive position has improved somewhat since the last report. In the recent comparison of the external cost burden of U.S. manufacturers when compared with nine major industrial countries, MAPI found that the U.S.' cost burden had been reduced from 31.7 percent of production costs to 17.6 percent.⁵

There is also some information showing foreign competitive advantage may be diminishing with respect to outsourcing decisions, especially vis-à-vis China. The source is the annual Michigan State-AMR Research survey of supply chain risk. China leads all countries as a source of supply chain risk, partly due to its importance as an international supplier. But, in the past year there has been a sizable increase in key supply chain risks—notably supply failure, quality failure and intellectual property infringement.⁶

⁵ Leonard (2008).

⁶ O'Marsh, K. *Supply Chain Risk, 2008-2009: As Bad as It Gets*, AMR Research, May 21, 2009.

Chart 2. U.S. Imports and Exports of Manufactured Products



Source: U.S. Census Bureau

JPC/ECS

C. Exports

If there was one bright spot in manufacturing performance in the past few years, it was the surge in manufacturing exports in response to the decline in the value of the dollar. Between February 2002 and July 2008, the dollar's value fell about 26 percent.⁷ Exports of manufactured goods from the U.S. grew at an average annual pace of almost 9 percent between 2002 and 2008. However, the trade deficit for manufactured goods continued to climb until 2006, peaking at \$631 billion before declining to \$578 billion in 2008. That decline reflected a 16 percent increase in manufactured exports during those two years and a slowdown in manufactured import growth to 5 percent. (Chart 2) This strong increase in U.S. exports during the time the value of the dollar was declining demon-

strates that there is considerable worldwide demand for the products of U.S. industry and it is fairly price sensitive.

Unfortunately, world trade has collapsed since the recession has taken hold. In August 2009, the volume of world trade was down 18.1 percent from its peak in April 2008.⁸ This collapse is reflected in the 23 percent decline from year earlier levels in the value of manufactured exports during the first nine months of 2009. (Similarly, the value of U.S. imports of manufactured goods has also fallen sharply, down about 25 percent.)

Despite the upswing in exports during the period the dollar declined, the U.S. share of world manufactured exports, as of 2008, dropped to only 9.2 percent, down from almost 14 percent in 2000.⁹ The U.S. has fallen to third place behind Germany and China since the 2006 report

⁷ The dollar's status as a safe haven in times of turmoil caused it to rebound almost 18 percent against other currencies between July 2008 and March 2009, although it has drifted down about 8 percent since the markets have stabilized.

⁸ *World Trade Monitor*, October 2009, CPB Netherlands Bureau for Economic Policy Analysis.

⁹ Since the WTO measures trade shares in dollar terms, part of this decline in share is due to the weakening in the value of the dollar against the currencies of other major exporters.

was completed. China took over first place as the largest exporter of manufactured goods in 2008. However, Germany and China are much more manufacturing oriented than is the United States. Manufacturing accounted for 23 percent of German GDP in 2007 and 34 percent of Chinese GDP compared to about 12 percent in the U.S.

The U.S. sends its industrial products around the world, with about a third of its 2008 exports going to Canada and Mexico, a quarter to Europe, a quarter to Asia and 10 percent to Central and South America. China shows a similar pattern to the U.S., with about a third of its exports going to Asia (some for re-export to other non-Asian countries), a quarter to North America and a quarter to Europe. Overall, Europe is much more likely to export its

The U.S. sends its industrial products around the world, with about a third of its 2008 exports going to Canada and Mexico, a quarter to Europe, a quarter to Asia and 10 percent to Central and South America.

industrial products to other European countries, with only about 8 percent going to North America and 8 percent going to Asia. Germany tends to follow the European pattern, although it has a slightly broader base than does Europe overall; but those European sales somewhat protect its export industries from the vacillations in the exchange rate that impact U.S. exports.

One subset of U.S. industrial exports deserves special mention because of its relationship to the innovative process; it is what the Commerce Department refers to as Advance Technology Products (ATP). These are broken down into ten major categories and include products from

many of the industries that have the highest R&D intensities in the U.S.¹⁰ In 2008, these products made up 29.6 percent of U.S. exports of manufactured goods down from 32.2 percent in 2006. ATP products were 22.2 percent of U.S. manufactured imports in 2008, up from 20.5 percent in 2006. This data highlights a longer term and concerning trend for high technology products. Prior to 2000, the U.S. ran a trade surplus with the rest of the world in these products. In 2000 and 2001, ATP trade was about balanced. However, since 2001, the U.S. has run a consistent trade deficit in advanced technology products overall. (Chart 3) In 2008 the U.S. still had surpluses in half of the ten categories: aerospace, biotechnology, electronics, flexible manufacturing and weapons. In addition, the U.S. had only a small deficit in advanced materials and may see almost balanced trade in that sector in 2009. However, the remaining categories were in deficit: life sciences, opto-electronics, nuclear technology and information and communications.

The U.S.' largest surpluses are in aerospace, \$49.7 billion, and electronics, \$25.9 billion. The largest deficits are for information and communications equipment, with a deficit of \$104.4 billion in 2008, opto-electronics, with a deficit of \$20.6 billion, and life sciences, with a deficit of \$14.8 billion.¹¹ However, even in the areas where the U.S. has trade surpluses, it has lost world market share since 2000. The U.S. share of semiconductor exports has fallen from 20 percent to 12 percent as it has shifted to a more global business model in that industry.¹² In machinery and transport equipment, the U.S.' share has fallen from 16 percent of world exports of those products in 2000 to 10 percent in 2008 although the share has drifted down only a small amount since 2003, the period of strong export growth discussed above.

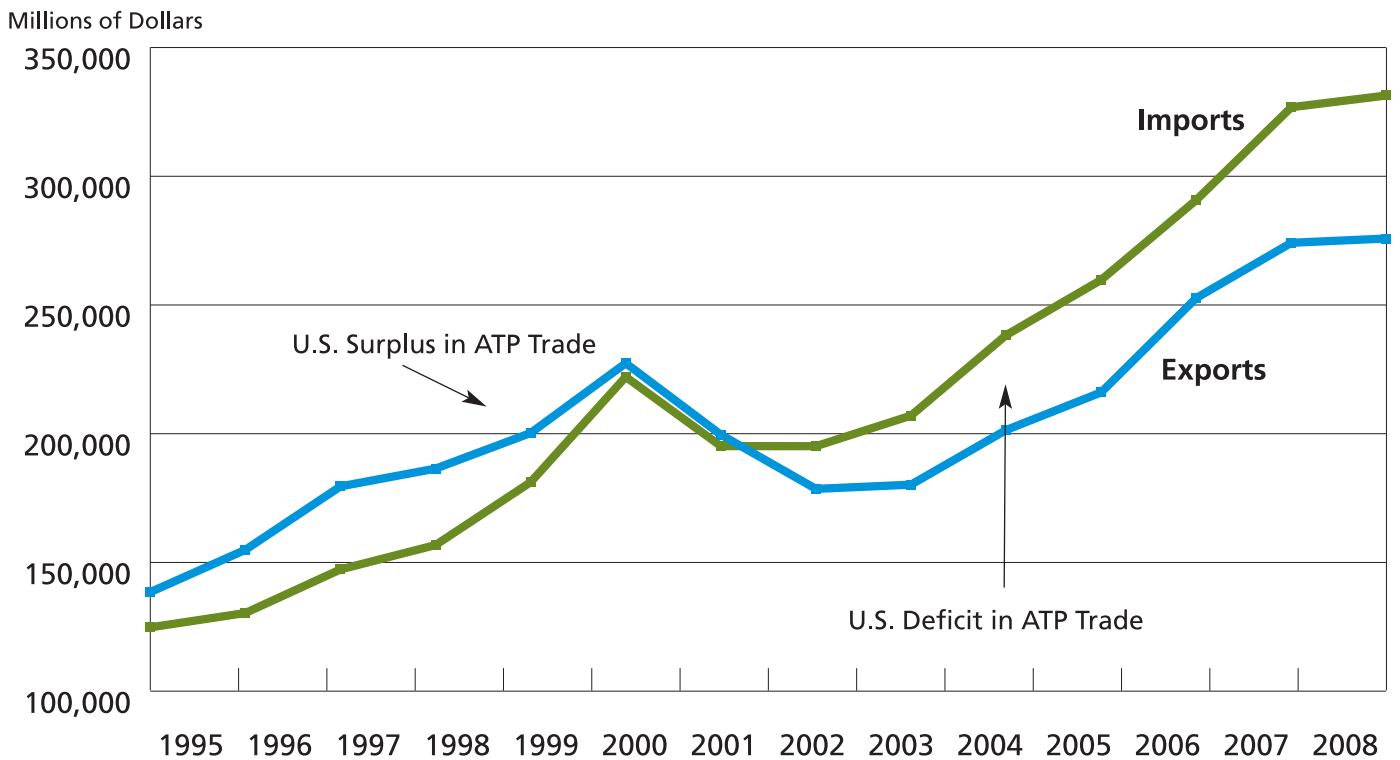
Exports are vital to the U.S. economy as payment for our imports. But, this analysis suggests there are leading-edge sectors where U.S. leadership has diminished. The responsiveness of exports overall to a fall in the value of the dollar is hopeful; it suggests that narrowing the U.S.

¹⁰ The ten major ATP categories are: biotechnology, life science, opto-electronics, information & communications, electronics, flexible manufacturing, advanced materials, aerospace, weapons and nuclear technology.

¹¹ The U.S. trade deficit with China in the information and communications sector was \$76.7 billion in 2008 (compared to a \$24.2 billion deficit in 2002). A significant part of the trade deficit in opto-electronics was the deficit with China, \$6.4 billion in 2008 (compared with a deficit of \$1.2 billion in 2002). However, the U.S. still has a small trade surplus with China in life sciences, \$334 million.

¹² U.S. electronic and semiconductor companies frequently use offshore fabs and assembly plants to produce all or part of their output. At that point some of the offshore production is imported into the U.S. to serve domestic markets.

Chart 3. U.S. Imports and Exports of Advanced Technology Products



Source: U.S. Census Bureau

JPC/ECS

competitive disadvantage can help restore the health of the industrial sector.

D. Employment

Along with manufacturing output, employment in the sector also has dropped considerably. This is a characteristic of manufacturing during recessions. Until 1979 manufacturing employment had regained its previous peak after each recession. That changed with the 1981-83 recession after which industry employment has persistently contracted. Service sectors, partly benefiting from manufacturing’s high multiplier effect on demand for their output and their relatively lower productivity, have continued to add jobs. The manufacturing sector’s strong productivity growth limits its direct job creation ability, but has historically contributed considerably to overall productivity growth in the U.S. economy.

A New York Fed study found that the percentage of high-skill workers in manufacturing rose between 1983 and 2002 and at the same time the share of low-skill jobs shrank.¹³ While a similar comparison of 2002 and 2008 finds little change in manufacturing’s share of high-skill workers overall, it does show that in R&D intensive industries, the share of high-skill workers has continued to increase. This has resulted in a modest increase in wage levels in the sector.

This modest shift to higher paying jobs is apparent from a comparison of the two major wage indexes from 2001, the end of the last recession to June 2009. One is the ECI for manufacturing, a measure that follows wages for sample-selected occupations and the average hourly earning index that is calculated by dividing payrolls by hours worked. The index that controls for the mix of employees, the ECI, rose 21.4 percent during that period while the

¹³ Deitz, R. and J. Orr. “A Leaner, More Skilled U.S. Manufacturing Workforce,” Current Issues in Economics and Finance, Federal Reserve Bank of New York, March 2006.

average hourly earnings index rose more quickly, up 22.8 percent, indicating the mix of employees was moving somewhat toward the more highly-paid workers.

E. Research and Development

R&D has not shown a significant weakening according to the data available through 2007, but early indicators are that the recent crunch in cash flow will have an impact on at least some spending for R&D in 2008 and 2009. In the 2006 report, manufacturing innovation was considered to be at modest immediate risk, its situation has worsened due to the recession. In-depth analysis of R&D spending is found in Section IV.

F. The Short Term Outlook

Manufacturing and construction were expected to spark a rebound in the economy and, increasingly, that view appears to be justified. The issue has now become the speed of recovery and its sustainability. Manufacturing growth is

one key element in a recovery's pace. Manufacturers are usually agile enough to adjust inventories and restocking them helps spark a rebound. U.S. manufacturers supply a large domestic population. Increases in manufacturing production begin to feed into all sectors of the economy as incomes and demand begin to pick up. One premise of the government's "Cash for Clunkers" program was to jumpstart such a process, but that activity alone was not enough to sustain a recovery. Other demand must also start to increase. Manufacturers' export growth will still be dependent on a recovery in the rest of the world. An adequate supply of funds at rates that make production and investment economically feasible is also needed to ensure a solid recovery, a particular concern in this recovery.

The next three sections detail the contribution of manufacturing industries to U.S. domestic growth, innovation and productivity.

III. The Key Contribution of Manufacturing Output

Manufacturing has long been recognized as one of the major contributors to U.S. growth. A decade-old U.S. Commerce Department study, *Engines of Growth: Manufacturing Industries in the U.S. Economy* concluded: *Simply put, manufacturing exercises the economy more broadly than other kinds of production activity.*

That conclusion relies heavily on the high multiplier of the manufacturing sector. (Chart 4) A dollar's worth of direct demand to the manufacturing sector induces another \$1.41 of supporting production. Almost a quarter of that induced secondary production is in manufacturing itself, but over half of the remainder raises output in non-government service sectors. Manufactured products are also significant inputs to the service sectors, providing 20-30 percent of the inputs they purchase from sectors outside their own. The manufacturing share is undoubtedly higher than these statistics indicate because the multipliers do not incorporate the induced increases in plant and equipment investment; and capital goods manufacturers—here and abroad—produce the equipment for such expansions. One major result of the decline in the manufacturing share over the past decade is that the smaller the manufacturing share, the less impact its high multiplier has in promoting growth in other sectors of the economy.

Those who study economic growth view it as a process of “creative destruction,” a term attributed to Joseph Schumpeter. The manufacturing industries are constantly undergoing this process.¹⁴ That is why the Commerce Department report speaks in plurals—“manufacturing industries” and “engines of growth.” Growth rates vary widely among such industries reflecting the impacts of changing technologies, competitiveness and consumer tastes and income. These forces have impacted the composition of manufacturing industries and their growth rates.

Another growth contribution of manufacturing is through its exports. Economic growth is driven by domestic productivity and market growth. If U.S. trading partners are growing faster, their imports from the United

States will grow faster as well, augmenting the growth rate dictated by the domestic forces just enumerated. Mature economies face growth slowdowns as their populations expand more slowly. Strong export growth is the vehicle by which mature economies keep their overall growth rate at acceptable levels.

Research has found that exports help improve productivity growth and can play almost as important a role as R&D does. A study of the Taiwanese electronics industry indicates that producers improve their plant productivity through both exporting and R&D. Interestingly, there did not seem to be much impact of exporting on R&D or vice versa. When compared to plants that neither exported nor invested in R&D, productivity growth in plants that did export increased by almost 2 percent, productivity in plants that invested in R&D increased by almost 5 percent and the plants that did both experienced productivity gains almost 6 percent higher.¹⁵ Since exporting activity is more broadly based across companies than is R&D, this productivity-enhancing role of exports can play a significant role in boosting productivity growth in the economy.

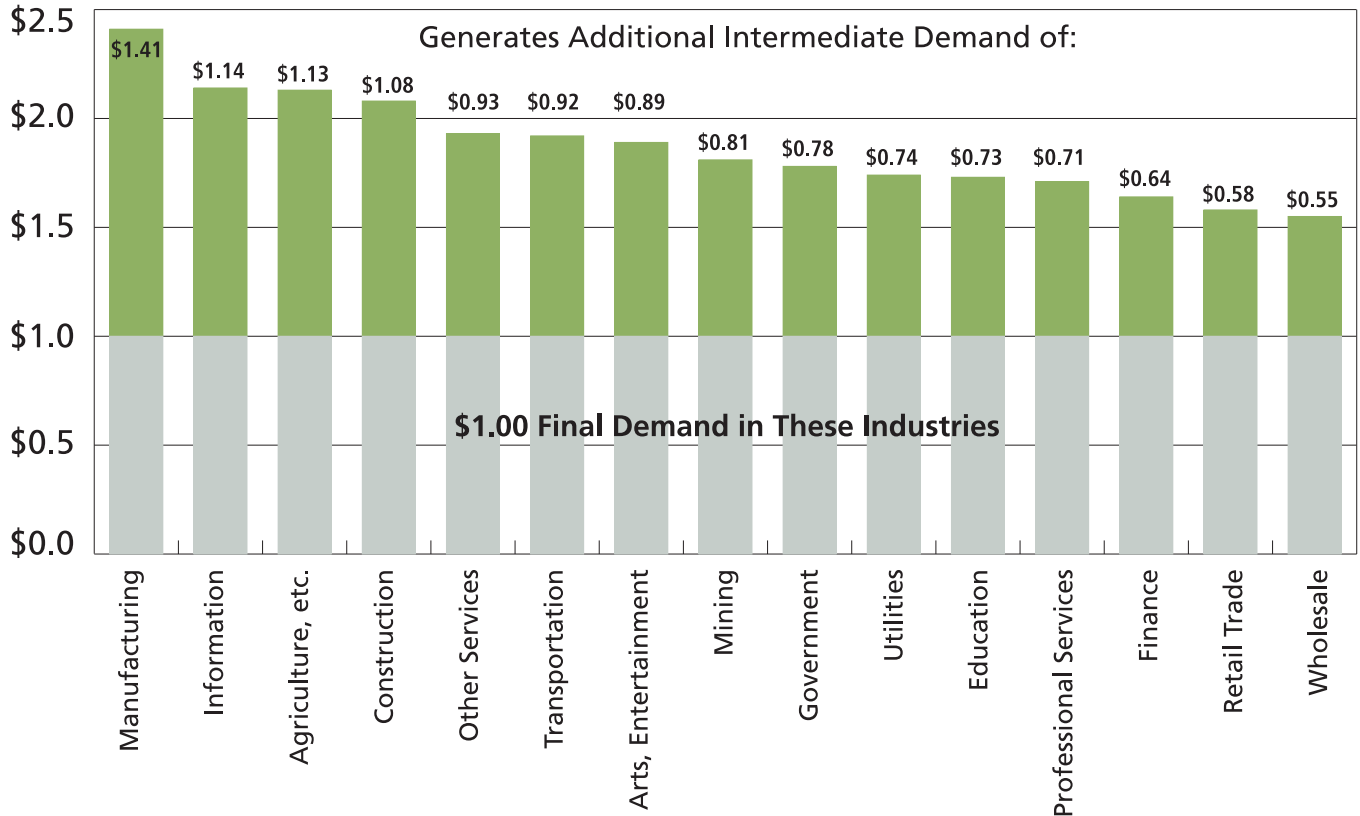
The U.S. is highly dependent on exporting manufactured goods. As can be seen from Chart 5, 50 percent of U.S. exports in 2008 were of manufactured goods (albeit down from 53 percent in 2007), 30 percent were services and 20 percent were a combination of agricultural products, minerals and fuels, and miscellaneous goods, including re-exports. About 15 percent of total U.S. exports (and 30 percent of manufactured goods exports) were of advanced technology products. During the first half of 2009, a year in which trade volumes have plummeted, manufactured exports were still 48 percent of all U.S. exports and a third

¹⁴ A current reminder of the dynamics is the conclusion reached by Thomas Seibel, an IT pioneer, that the IT industry has reached maturity, i.e., its growth rate will only mirror the growth of the overall economy in the future. (“Are the Glory Days Long Gone for I.T.?”, R. Stross, *The New York Times*, August 8, 2009). While other experts disagree with this assessment, this debate highlights the constant evolution of the manufacturing sector.

¹⁵ Aw, Bee Yan, M.J. Roberts and D.Y. Xu. *R&D Investment, Exporting and Productivity Dynamics*, NBER working paper W14670, January 2009.

Chart 4. Manufacturing's Linkages to the Rest of the Economy

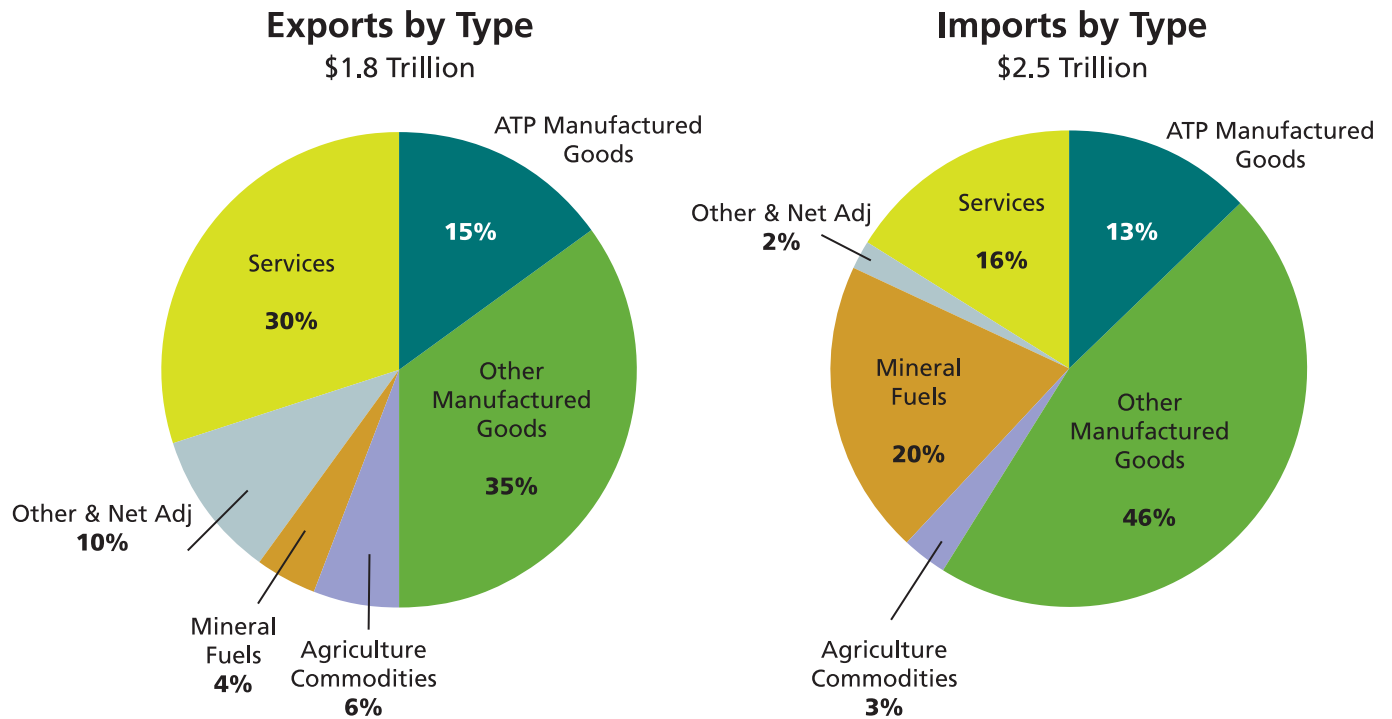
Intermediate Demand Necessary to Produce \$1.00 of Final Demand



Source: U.S. Bureau of Economic Analysis, From 2007 Industry-by-Industry Total Requirements

JPC/ECS

Chart 5. Breakdown of U.S. Exports and U.S. Imports by Type (2008)



of those exports were advanced technology products. Almost 60 percent of all U.S. imports were manufactured goods (with 13 percent of all imports being advanced technology products), 20 percent of imports were fuels and 16 percent were services.

Strong export growth is the vehicle by which mature economies keep their overall growth rate at acceptable levels. Research has found that exports help improve productivity growth and can play almost as important a role as R&D does.

As the U.S. share of manufactured exports has fallen, it has been suggested that service sector exports will fill the gap if the volume of U.S. goods exports contracts. However, that is a hard case to make. In 2008, U.S. exports of services totaled \$549.6 billion. Service exports have expanded from \$304.3 billion in 2003, a growth rate of slightly over 12.5 percent per year. That is a faster rate of growth than the average annual increase of 8.5 percent experienced by manufactured exports during the same time period. However, services are not immune from the downturns in the economy. Manufactured exports during the first nine months of 2009 were almost 23 percent below the value of those exports during the same period of 2008. But services exports also declined, falling 11 percent during the January-September 2009 period when compared with the similar period a year ago.

Also, a relatively large percent of service exports are tied to air travel and tourist receipts and decline cyclically during weak economic periods. However, about a quarter of the 2008 receipts were generated by two service sector categories that are closely tied to goods-related activities. The first is transportation costs of goods, which show up in other transportation costs. These consist of air and ocean freight and port costs. The second is royalty and licensing fees. In 2007, 45 percent of the royalty and licensing fees received by the U.S. were for industrial processes; and those fees were \$10 billion larger than the next largest category, fees for general use computer software. Both the other transportation and royalty and licensing fee categories have declined during the first nine months of 2009, 28 percent from year-earlier levels for the other transportation category and almost 13 percent from year-earlier levels for royalties and licenses.

However, more problematic for the growth in service exports may be the fallout from the recent financial meltdown in the United States. Almost 15 percent of service exports are financial services and insurance. More importantly financial service has been one of the fastest growing of the service exports, more than doubling in the past five years. That rate of growth is unlikely to be matched any time soon. These factors, taken together, show that it is not realistic to think that in the next several years service exports will be able to replace manufactured goods exports that are almost twice their size.

IV. The Innovation Process: Manufacturing's Key Role

In the long run, innovation is the keystone of U.S. productivity growth and increases in the U.S. standard of living. The process by which R&D drives that

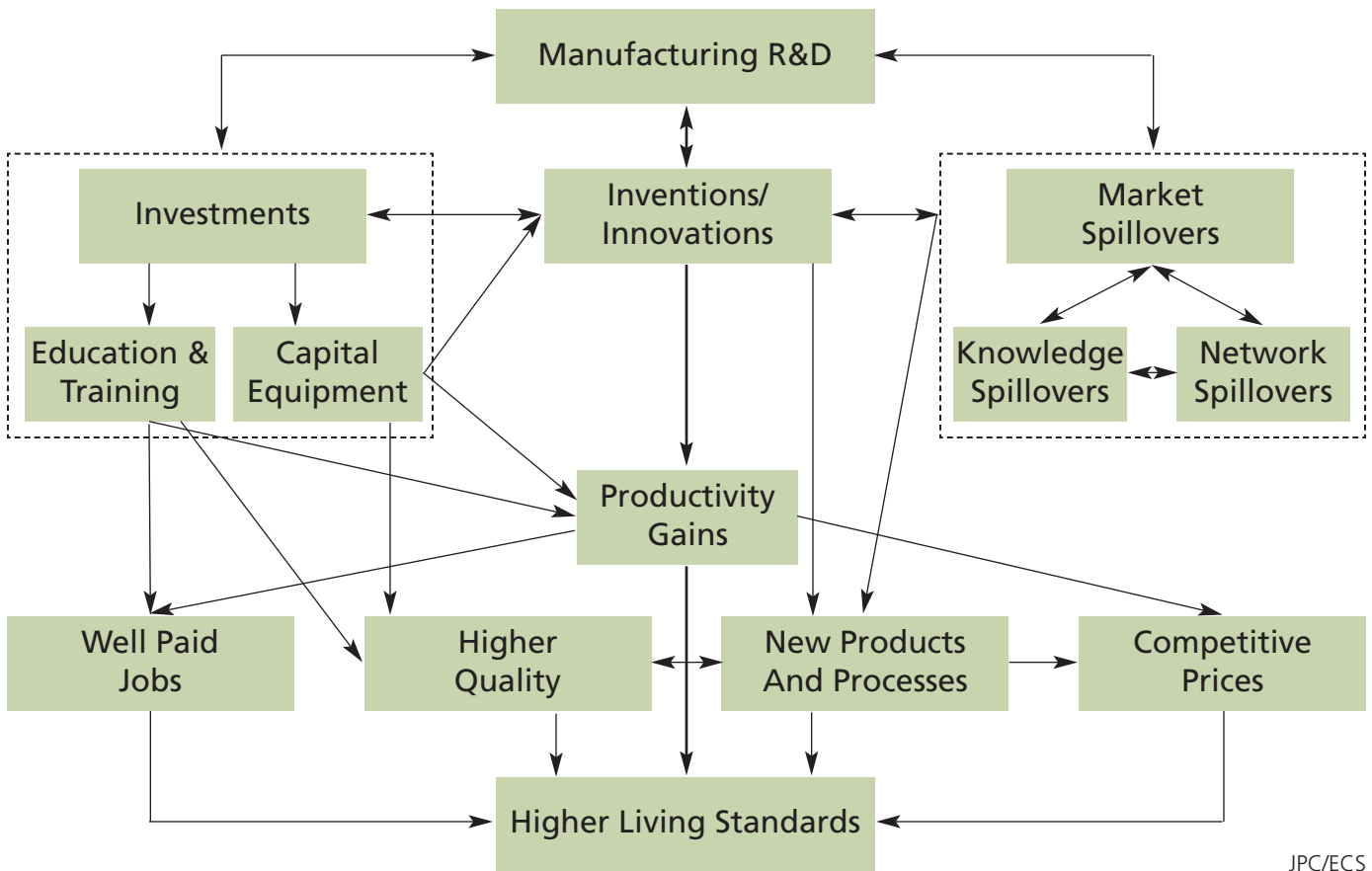
continual improvement is depicted in Figure 1, a version of which appeared in both prior studies.¹⁶ The diagram illustrates the channels through which R&D flows to benefit productivity, U.S. competitiveness and our standard of living and the feedbacks that prompt the next round of change. Spillovers function as an important part of the innovation process by generating more bang for the buck for

the overall economy than an individual company making the R&D investment may see.

A. Research and Development Activity

When the 2006 report was written, the U.S. was still the clear leader in research and development.¹⁷ It is still the leader in the absolute number of dollars spent. However,

Figure 1. Manufacturing Matters: Its Innovation Process Generates Wealth



JPC/ECS

16 For a more detailed description of the processes depicted in Figure 1, see *U.S. Manufacturing Innovation at Risk* (February 2006) and *Securing America's Future: The Case for a Strong Manufacturing Base* (June 2003) by Joel Popkin and Kathryn Kobe for the NAM Council of Manufacturing Associations and The Manufacturing Institute.

17 Research and development activity has been defined most recently by the NSF for use in its newly redesigned and fielded R&D survey. Research is defined as planned, systematic pursuit of new knowledge or understanding. Development is the systematic use of research and practical experience to produce new or significantly improved goods, services or process. Research is subdivided into two components. Applied research is activity aimed at solving a specific problem or meeting a specific commercial objective. Basic research is activity that is aimed at acquiring new knowledge as understanding, without specific immediate commercial application or use.

its strong R&D position is being eroded by the impact of the economic downturn and its leadership is being challenged by the rapidly expanding R&D programs in other countries. The U.S. share of world R&D will likely fall in 2009.

Total U.S. industrial R&D (R&D performed by businesses) rose 8.7 percent between 2006 and 2007 to \$269.3 billion. In real terms, after correction for inflation, industrial R&D rose by 5.6 percent.¹⁸ Manufacturing companies performed 70 percent of the 2007 industrial R&D in 2007, spending \$187.5 billion. (Chart 6) Of that amount, manufacturing companies funded \$169.3 billion and federal funding accounted for an additional \$18.2 billion. Manufacturing companies spent almost 3.7 percent of sales on R&D in 2007, up a bit from 3.6 percent in 2006.

The National Science Foundation does not yet have data for a period more recent than 2007.¹⁹ Other sources of information indicate that R&D funding continued to increase in the early part of 2008, but the severe economic downturn has resulted in mixed reports for 2009.²⁰ A review of 28 of the U.S.' largest R&D spenders (excluding autos and pharmaceuticals) indicated that R&D spending in the fourth quarter of 2008 declined slightly from year earlier levels; however, that was substantially less than the 7.7 percent decline in sales, indicating that R&D intensity was perhaps slightly stronger than average.²¹ The Industrial Research Institute's survey on expected 2009 R&D expenditures revealed that its member companies were planning virtually no change in their R&D expenditures in 2009.²² But, in its annual R&D funding forecast

(updated in June 2009) *R&D Magazine* and Battelle reported that it expected U.S. and European R&D spending to decline between 2008 and 2009. Early numbers indicate that R&D by European businesses held up better than did U.S. and Japanese R&D spending during 2008, but data are not yet available for 2009.²³ In the meantime, China and India continue to increase investments in R&D.²⁴

A declining share of world R&D is almost inevitable as countries that previously had virtually no R&D infrastructure begin to build one. China and India, while impacted by the global recession, are still expected to see much stronger economic growth in 2009 and 2010 than the developed countries will experience.²⁵ Given the continued growth in their economies and the focus these countries have on building an R&D base, it is expected that the U.S. and other developed countries will continue to see their shares of world R&D spending erode in the next few years.

But a general loss of world share is only one indicator that the U.S.' position as world R&D leader is more precarious. The industries that fund the largest amount of U.S. R&D have been severely hurt during the recession. The six industry sectors that spend the largest amount of company funds on R&D are: pharmaceuticals (20 percent of company funded R&D), software publishing (9 percent), semiconductors (8 percent), motor vehicles (7 percent), computer system design (6 percent) and aerospace (6 percent). Output in these sectors has been hit hard by the recession. (Chart 7) Even pharmaceuticals, usually a recession-proof industry, saw some declines in its output.

¹⁸ Wolfe, Raymond. *U.S. Business R&D Expenditures Increase in 2007; Small Businesses Performed 19% in Nation's Business R&D*, NSF 09-316, July 2009.

¹⁹ The NSF has instituted a new survey on R&D to collect information for 2008. It is unclear as of yet when those data might become available and how they will relate to the time series R&D data through 2007.

²⁰ The Industrial Research Institute, an association of companies and federal laboratories working together to improve their research and development capabilities, surveys their members on R&D plans annually in the summer of the year prior to the year for which the projections are collected. In responses IRI collected in the summer of 2007, fully 88 percent of the respondents indicated they planned on increasing R&D spending during 2008, 38 percent indicated they would increase it by 5 percent or more. However, there is little information on the actual experience related to 2008 R&D expenditures. In a joint report, the Pharmaceutical Research and Manufacturers of America and Burrill & Company estimated that U.S. R&D investment in new medicines by the biopharmaceutical industry was up 3 percent from 2007. *R&D Spending by U.S. Biopharmaceutical Companies Increases 3 Percent in 2008*, Reuters, March 10, 2009.

²¹ Scheck, Justin and P. Glader. *R&D Spending Holds Steady in Slump*, The Wall Street Journal, April 7, 2009.

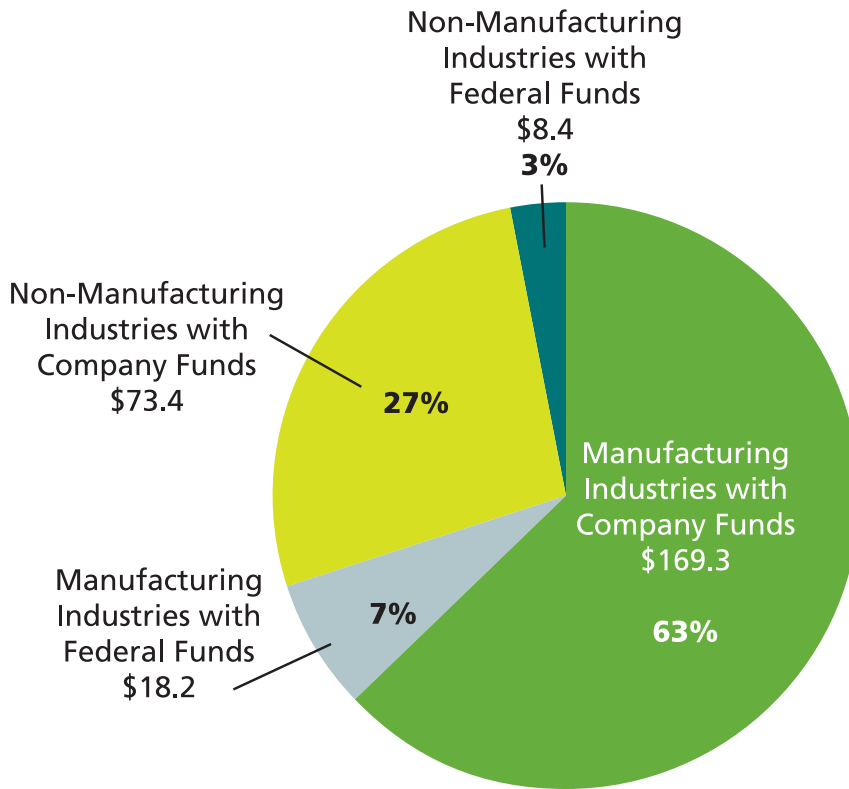
²² *U.S. Companies to Hold the Line on R&D Spending in 2009*, Industrial Research Institute, February 19, 2009.

²³ Nikki Tait, "Europe Puts Stress on R&D Spending," *Financial Times.com*, November 17, 2009.

²⁴ *2009 Global R&D Funding Forecast and Update*, R&D Magazine, December 2008 and June 2009.

²⁵ The International Monetary Fund's latest update expects GDP growth rates of 8.5 percent and 5.4 percent for China and India respectively in 2009, while the GDP of the developed economies is expected to decline 3.4 percent. The developed economies will grow at about a 1.3 percent rate in 2010. China and India are expected to grow 9 percent and 6.4 percent. *World Economic Outlook*, International Monetary Fund, October 2009.

Chart 6. Performers of 2007 Industrial R&D by Source of Funds
(Billions of Dollars and Percent)



The hardest hit was the motor vehicle industry, where two of the largest companies filed for bankruptcy and are now undergoing extensive restructuring. Output in that sector was only half of December 2007 levels during the first half of 2009 and is still down by more than 25 percent. The semiconductor industry also experienced extremely poor business conditions with sharply lower production and several of its companies entered bankruptcy.²⁶ While the worst seems to be over for most of these industries, the fallout of the recession continues. Companies undergoing major restructuring face an additional amount of

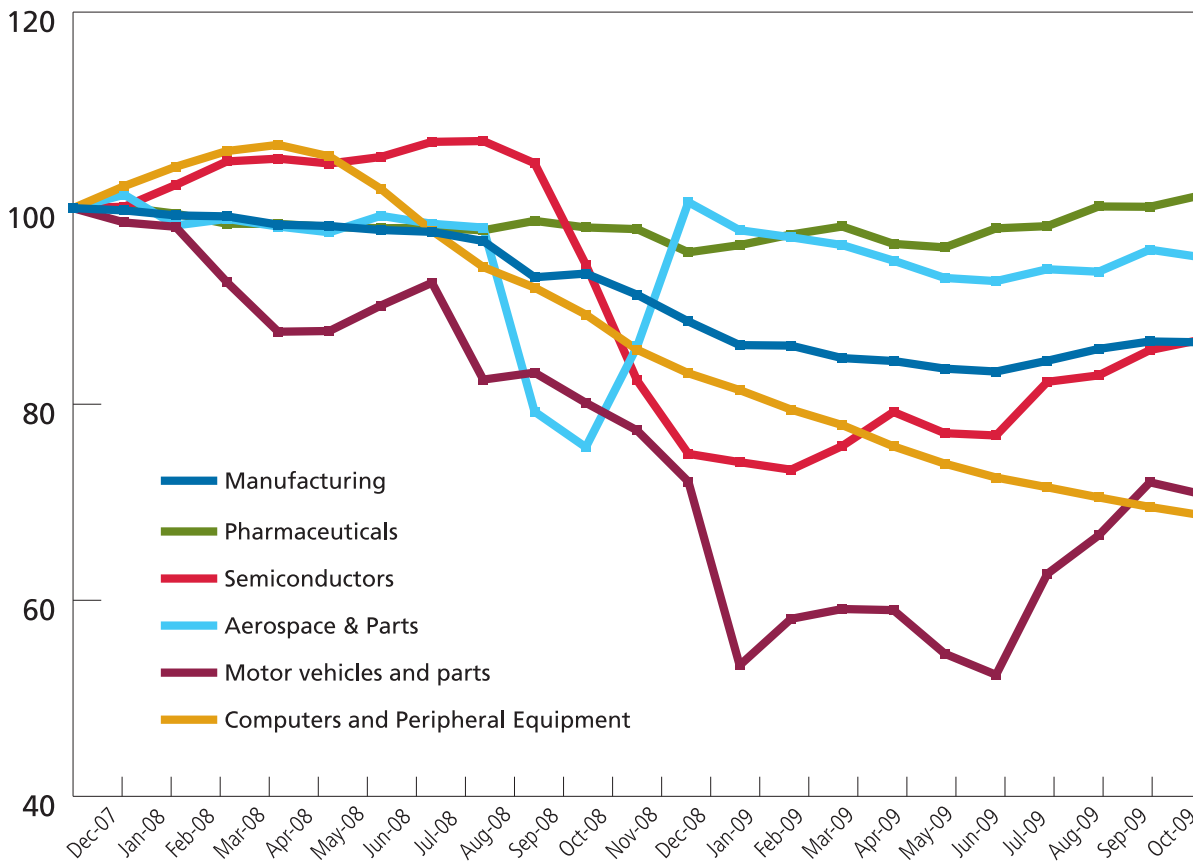
risk and uncertainty associated with any contemplated R&D investments as they reassess their business plans. While the stimulus money that has been targeted for R&D will help soften the blow, sales are weak and absolute R&D levels are likely to be pinched. The large companies responding to *The Wall Street Journal* survey indicated that they were protecting R&D as much as possible and not cutting it as much as their revenues are declining, but that is not a scenario for robust growth in R&D.²⁷

The absolute amount of money that an economy devotes to R&D is important, but the intensity of R&D, the

²⁶ The bankruptcy of German semiconductor manufacturer, Qimonda, has resulted in the shutdown of its U.S. semiconductor fabrication plant (see semiconductor.net "Qimonda to Close Virginia Fab," February 6, 2009) and the closure of its U.S. R&D facilities. At the same time, Qimonda's R&D center in Xinhua China is being taken over by Inspur Group, the founder of China's computer server industry. (see *China Daily* "China's Inspur takes over Qimonda R&D center," August 13, 2009). Intel also announced the closure of the last semiconductor fab in Silicon Valley, California (see Intel press release, January 21, 2009). While this decision was undoubtedly influenced by the poor economy, it is more an example of the dynamic nature of manufacturing and R&D. Intel also announced plans to invest \$7 billion in more advanced semiconductor technology in U.S. manufacturing facilities over the next two years (see Intel press release, February 10, 2009).

²⁷ Schumpeter and others have presented various theoretical arguments for recessions encouraging more R&D spending, one of the most notable being that a slow production period is the ideal time for companies to invest in productivity enhancing activities that may also tend to disrupt production, such as installing new equipment and retraining workers. However, empirical evidence suggests that R&D declines during recession rather than increases. Gadi Barlevy suggests that is because firms have the best chance of profiting from their innovations during boom periods and may not want to risk their research being revealed to others before they are ready to take advantage of its results. See *Why don't recessions encourage more R&D spending*, Chicago Fed Letter, November 2005.

Chart 7. Output of All Manufacturing and Major R&D Intensive Industries Since the Start of the Recession (December 2007 = 100)



percent of GDP or sales spent on innovative activities, is more often used as an indicator of relative competitiveness. In 2006, the U.S. spent an amount equal to 2.6 percent of its GDP on R&D. That was slightly ahead of the OECD average of 2.3 percent.

U.S. manufacturing's R&D intensity is measured by comparing the amount of company funds used for R&D to its sales. That ratio has shown some improvement in recent years, up from 3.4 percent in 2004 to 3.7 percent in 2007. The 2007 number matches the last peak of 3.7 percent in 2001. Chart 8 shows the industries that are devoting the largest percentage of sales to R&D activities. Among the manufacturing industries are: communications equipment (14.7 percent), pharmaceuticals (12.7 percent) and semiconductor equipment (12.0 percent), all

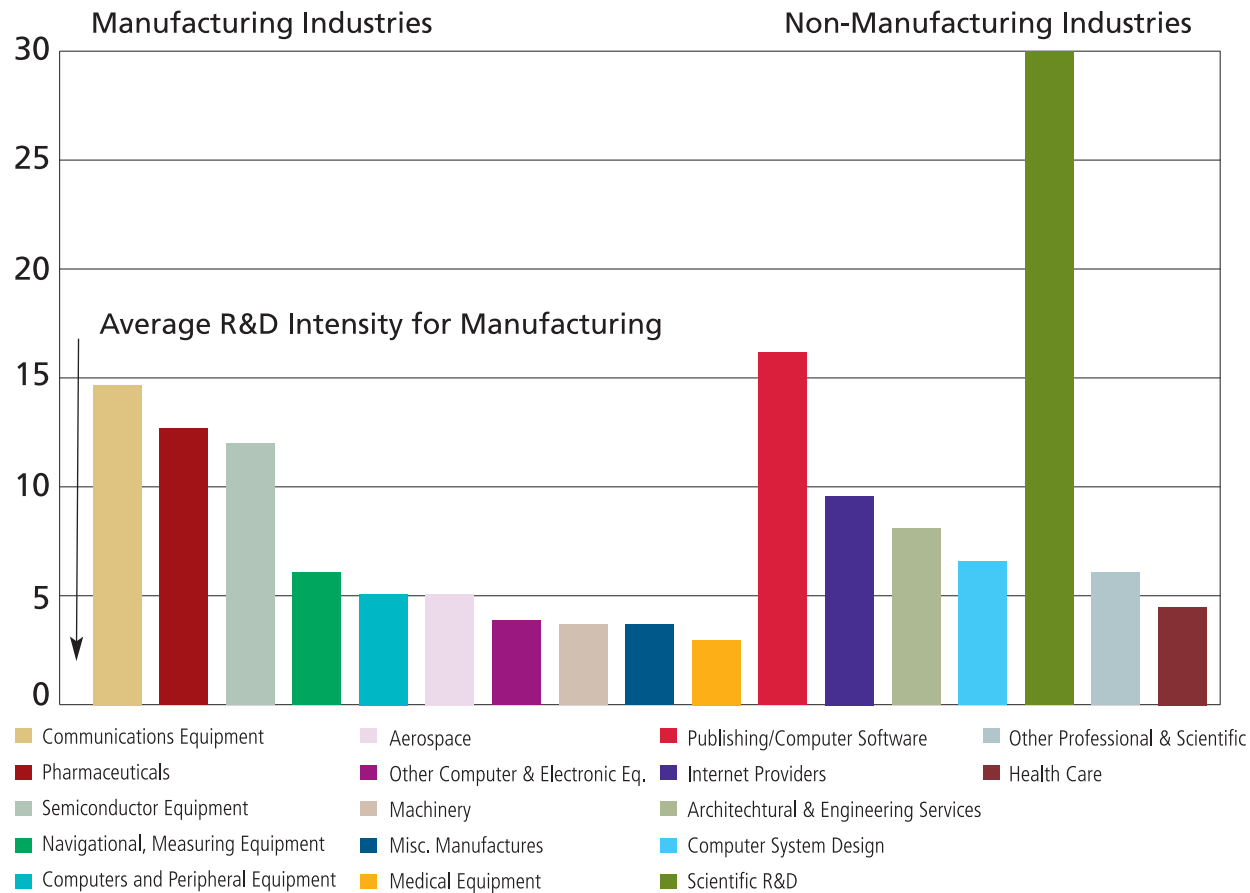
well above the average. Medical equipment, a sector that had an R&D intensity of 6-10 percent of sales during the 2004-2006 period, dropped below average in 2007, investing only 3 percent of sales in funding R&D.²⁸ Many of the industries with the highest R&D intensity are also sectors that are considered Advance Technology Products under the Commerce Department's classification (see footnote 9 for a listing). As discussed in an earlier section, those are important in helping to increase U.S. exports by producing cutting-edge goods that consumers and businesses in other countries are demanding.

Chart 8 also shows the non-manufacturing sectors with the highest R&D intensity. Many of those are closely related to and driven by demand from manufacturing industries.²⁹ Several of those industries reflect the software

²⁸ R&D intensity within a category varies depending on product mix and other factors of the specific companies, but most of the companies within a particular industry show similar intensities. For example, the large U.S. semiconductor companies showed total 2007 R&D intensities (whether performed in the U.S. or abroad) that varied from Motorola's 9.6 percent of sales to Advance Micro Device's 21.3 percent of sales and with most companies falling in the mid to high teens. The two large U.S. aerospace companies both had single-digit intensities with Boeing at 5.3 percent and Lockheed Martin at 2.9 percent. See *IEEE Spectrum's* Top 100 R&D Table, November 2008.

²⁹ Health care services (4.5 percent) is an exception, with few direct ties to manufacturing; it has gone from below average intensity in 2004, investing only 1.8 percent of sales in R&D, to above average intensity.

Chart 8. Industries with High R&D Intensities



and content side of the R&D that is done in the computer and electronic sector on the manufacturing side. For example, the production of applications for the iPhone would fall in the software publishing sector. The very highest intensity is in scientific R&D services, which logically has a very large percentage of its resources tied to research. Much of that industry reflects the contracting out of many of the R&D services that previously were being performed in-house and a large percentage of those services are being performed for the manufacturing sector. The *R&D Magazine*/Battelle R&D survey for 2009 revealed that almost 12 percent of U.S. R&D funds were being used to support R&D efforts that had been outsourced within the U.S. compared to 2.4 percent to support R&D outsourced to foreign performers.³⁰ The remaining R&D is still done internally, although some internal R&D is performed overseas in affiliates of U.S. companies.

One concern about U.S. innovative efforts is that not

enough money is spent on basic research, the general expansion of scientific knowledge. Industrial R&D is primarily applied research and development. Only about 3.5 percent or \$8.5 billion of company funds were spent on basic research in 2007. While that is down substantially from the 6.5 percent of funds that were spent on basic research a decade ago, companies have never spent more than 7 percent of their R&D funds on basic research since the NSF started tracking these numbers in 1953. As William Baumol has observed, the management processes of established businesses weigh the costs and benefits of all such activities. It is logical for businesses to lean toward the type of R&D that will produce the most certain and immediate returns. “The inherent conservatism of the process naturally leads to the expectation that these firms will tend to specialize in the incremental improvements and tend to avoid the risks of the unknown that the revolutionary breakthrough entails.”³¹ In the long run, basic

³⁰ *The Changing Face of U.S. R&D*, R&D Magazine, December 2008.

³¹ “Small Firms: Why Market Driven Innovation Can’t Get Along Without Them,” by William Baumol, *The State of Small Business*, Small Business Administration, 2005.

research has the potential to produce the revolutionary breakthroughs with the broadest applications, but it also has the greatest risk that any given research avenue will not provide a payoff. To increase the amount of basic research undertaken, policymakers can take a direct role by providing government funds directly or an indirect role by providing companies incentives to increase their R&D. The latter will be discussed in the next section.

Basic research is primarily done at academic institutions. Of the \$51.9 billion spent on scientific and engineering R&D at universities and colleges in 2008, \$39.4 billion, 76 percent, was for basic research. The bulk of academic R&D funds come from the government with about 60 percent from the federal government (down from 61 percent in 2007) and an additional 6½ percent from state and local governments. Only about 5½ percent came from private industry.³² Academic R&D is heavily weighted (almost 60 percent) toward the life sciences, mostly because over half of federal support is focused in that area.

Federal obligations for research and development showed almost no change between 2007 and 2008 and were down 1.9 percent after correction for inflation.³³ Moreover, federal support of basic research declined at an average annual rate of 1.5 percent between FY2004 and FY2008. The proposed budget for FY2009 increased federal outlays for research and development by 3.4 percent, with only a small increase for health research and the largest increases proposed for the space program and general science R&D.³⁴

The federal government is the primary source of funds for basic research at academic institutions, and, therefore, faces decisions about where the dollars are best spent. There are two relatively new initiatives in place to help develop an evidence-based platform to assist in evaluating how science and technology leads to innovation and growth. The NSF's Science of Science and Innovation Policy (SciSIP) initiative is tasked with developing met-

rics, datasets and experts to provide guidance in making informed decisions about which broad areas such as health, energy, nanotechnology, space exploration, etc. have the potential to make the most from government funded basic research. In addition the President's Council of Advisors on Science and Technology (PCAST) may help decide which broad areas have the most potential. These will be helpful in supporting the government's decision making and may provide helpful insights to other funders of basic research as well.

The loss of world R&D share is a relatively simplistic measure of the U.S.' innovative position in a growing

To increase the amount of basic research undertaken, policymakers can take a direct role by providing government funds directly or an indirect role by providing companies incentives to increase their R&D.

global economy. Likewise, the recession's blow to major R&D spenders, while painful, will not stop U.S. R&D growth forever. However, the Information Technology and Innovation Foundation produced a more broad-based measure of the U.S.' competitive position that raises longer-term concerns about whether the U.S. will remain at the leading edge of innovation. In benchmarking U.S. and E.U. competitiveness, it found that the U.S. ranked sixth out of thirty-six countries on its competitiveness and innovation scale.³⁵ However, probably more telling given the inexactness of the scale, the U.S. scored at the bottom of the list when ranking how much the U.S. has done to improve its position in these areas over the last decade;

³² "Federal Government is Largest Source of University R&D Funding in S&E; Share Drops in FY2008," by R. Britt, National Science Foundation *Info Brief* (NSF-09-318), September 2009.

³³ "Federal R&D Support Shows Little Change in FY2008," by M. Yamaner, National Science Foundation *Info Brief* (NSF-09-320), September 2009.

³⁴ Bennof, R. "President's 2009 Budget Requests 3.4% Increase in R&D Funding," National Science Foundation *Info Brief* (NSF 08-312), July 2008.

³⁵ *The Atlantic Century: Benchmarking U.S. and E.U. Innovation and Competitiveness*, Information Technology and Innovation Foundation and European-American Business Council, February 2009. The scoring system includes more than just R&D spending, although that is one of the components. It also includes measures of human capital, entrepreneurship, information technology infrastructure, public policy and economic performance.

China and Singapore ranked 1st and 2nd. This analysis is not manufacturing specific, but reinforces that the U.S. cannot take its role as global R&D leader for granted, the rest of the world is constantly gaining ground. The U.S. must focus its goals and move forward as well.

B. R&D Spillovers and Their Impacts

Actual spending on R&D can underestimate its full innovative impacts. That is because there are “spillovers.” In the earlier papers, spillovers were described as instances where benefits flow from R&D to economic units other than the company conducting the research without the latter being compensated. Spillovers help provide entrepreneurs the ideas that generate new businesses, perhaps out of an idea or ideas gained during a past job, perhaps from academic research or reading journals.

Companies invest substantial amounts in R&D because, while volatile, the overall payoffs can be substantial. A relatively large literature using a production function approach to estimate the return on R&D finds double-digit payouts in the range of 25-60 percent. More recent research using more refined assumptions estimates somewhat smaller return.³⁶ Whatever the actual rate of return, it is high enough to prompt firms to invest in R&D. However, the existence of spillovers assures that the return to society is even larger than the payback the firm funding the R&D is able to capture. Research designed to look at this issue found that social returns to R&D were about 3.5 times larger than the private returns confirming that firms do not have the incentive to invest as much as is beneficial to society.³⁷ Because spillovers leverage R&D expenditures for the benefit of the whole economy, there are solid reasons for policy to focus on two areas. First, policies that enhance potential spillovers increase the secondary benefit of R&D to society. Second, encouraging companies to spend more funds on R&D than the company otherwise would invest, such as with tax credits, partially compensates them for the portion of the return to their research that they are not able to capture directly.

This may be especially effective for riskier R&D, such as that related to basic research.

Spillovers are usually characterized in one of three ways, but these pathways often interact and increase their combined effect. One way is through “market spillovers,” in which the marketing of a new product creates benefits to market participants other than the innovating firm.³⁸ Often this is through a new technology that is embodied in products newly developed or improved by R&D. However, because producers fail to capture all 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. A second kind is termed a “knowledge spillover.” This is the transmission of knowledge from an R&D activity that can be used by other economic entities in a virtually cost-free manner. 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. For example, wi-fi allows greater benefits to be derived from computer use, and the more people one can communicate with in that network, the greater those benefits.

One of the outcomes of spillovers appears to be a clustering of high-tech companies in relatively small geographic locations. On the face of it, that would seem to be an odd result if companies want to keep their research to themselves. However, a second finding of the Bloom et al. study is that R&D performed by product rivals is a strategic complement to an own firm’s R&D. Companies investing in R&D not only create spillovers, but take advantage of spillovers from others. Thus, the benefits of proximity explain why companies in the same industry often cluster in high-tech centers where they can best take advantage of spillovers despite concerns of product market rivalry. Such benefits can be lost when R&D activities go offshore.

Other studies have tried to identify the various factors that result in this observed clustering. A recent article

³⁶ Warusawitharana, Mlssaka. “Research and development, profits and firm value: A structural estimation,” Federal Reserve Working Paper 2008-52, September 2008.

³⁷ Bloom, Nick, M. Schankerman and J. Van Reenen. *Identifying technology spillovers and product market rivalry*, Discussion Paper, Centre for Economic Performance, January 25, 2005.

³⁸ The potential for market spillover from Advanced Technology Program (ATP) projects was estimated in *Inter-Industry Diffusion of Technology that Results from ATP Projects*, by Joel Popkin, NIST GCR-03-848.

published by the Philadelphia Federal Reserve Bank, provides an overview of some of these arguments and presents findings from some of their researchers.³⁹ The authors found that the top 50 counties in the United States ranked by number of R&D labs accounted for 58 percent of all R&D labs while a similar analysis of manufacturing plants found that the top 50 counties accounted for only 36 percent of manufacturing establishments. Thus, R&D is more geographically clustered, a strong suggestion that there are spillovers to be captured. Another paper by one of the same authors studied the factors that seemed to be correlated with geographic areas of higher innovation (in this case measured by patenting rates for the cities). The study found that the most important variable was the magnitude of the human capital in the area (measured by the share of the adult population with a college degree). However, other findings were that areas with smaller businesses tended to have a higher patenting rate, although it is not clear if this is a cause or an effect. Patenting activity does seem to require a certain size of labor market and a certain density. An increase in local academic R&D generated only a modest increase in patenting rate in this study and the patenting rate was higher if the R&D was funded by sources other than the government although the authors note this may be the result of federally funded R&D being more basic research and less likely to result in immediate patents.⁴⁰

Clusters of high technology firms usually emerge in the vicinity of universities. This implies that spillovers surround these institutions. One important role for universities in the process is to help increase the magnitude of the human capital in an area both by concentrating well-educated academics and by training new researchers. Some states use those relationships to better focus their policies and development funds. One example is Texas' \$300 million investment in the engineering program at the University of Texas. That investment helped induce Texas Instruments to build its next generation chip facility in Texas because it would have access to the highly skilled students and fac-

ulty at the university, but the infrastructure investment also benefited other Texas high-tech firms and generally increased the country's investment in a skilled workforce.⁴¹

Universities themselves are also taking a more active role in interacting with private business and in fostering small business growth. This is important in order to more quickly move the findings of basic research into the market place where it can be tested and refined by market forces. The Association of University Technology Managers (AUTM) surveyed the activities of academic technology transfer professionals in 2007 and found that the respondent institutions had filed 17,589 patents during the year and had 3,622 patents issued. Furthermore, 686 new products were introduced into the marketplace based on their research and 555 new startup companies were established licensed to use that research.⁴²

A recent BLS analysis of R&D literature concludes that spillover effects on productivity must be measured to obtain reliable estimates of the contribution of R&D to multifactor productivity growth. In particular, this study notes that private returns to R&D and spillover returns follow different time paths, with the latter taking a longer time to be fully realized than the former. This supports the view that R&D stocks should be considered explicitly in calculating productivity. The author also stresses that most papers show that extremely high returns are related only with privately financed research, thus explaining why businesses use their own funds in research. Thus, while government can play a role to promote spillovers and increase investment in riskier types of research, government cannot replace private sector R&D as the backbone of the innovative process.⁴³

C. Sustaining vs. Disruptive Innovation And Business Size

Once R&D investments are made and the research conducted, translating that research into an innovative change that improves productivity and living standards is not al-

³⁹ Buzard, Kristy and G.A. Carlino. "The Geography of Research and Development Activity in the U.S." *Business Review*, Federal Reserve Bank of Philadelphia, Q3-2008, pp. 1-11.

⁴⁰ Carlino, Gerald and R. Hunt. "What Explains the Quantity and Quality of Local Inventive Activity," Federal Reserve Bank of Philadelphia working paper no. 09-12, June 2009. The paper also found a modest negative effect between earmarks of federal funds for academic R&D and patenting rates.

⁴¹ "The 2007 State New Economy Index: Benchmarking Economic Transformation in the States," National Governors Association.

⁴² *AUTM U.S. Licensing Activity Survey FY2007*, Association of University Technology Managers, 2008.

⁴³ Sveikauskas, L. *R&D and Productivity Growth: A Review of the Literature*, BLS working paper 408, September 2007.

ways easy. Some innovations can be small incremental changes that are relatively easily implemented, but others can be major new discoveries, sometimes accidental, and it takes time, money and imagination to use those to their full advantage.

Clayton Christensen in his book *Innovator's Dilemma* usefully classifies innovations into two categories. The first

19 percent of all R&D was performed by businesses with 5 to 499 employees. While they do not perform the largest amount of R&D among private sector companies in absolute terms, an impressive 85 percent of small business funding came from non-Federal sources.

is sustaining innovations, ones that improve a product or process along the general trend that the company and the market has expected. The second category is referred to as disruptive innovations, a new way of doing something that may be in direct conflict with an established product or method and at odds with the established market. It is often difficult for a large company to make full use of a disruptive innovation since it may conflict with a long established product line or method of doing something. Disruptive innovations may evolve into very important, productivity enhancing leaps in technology. However, they usually are introduced as a niche product and grow from there, often serving an entirely new group of con-

sumers before spreading to the broader market. These are the types of innovations that are sometimes best suited for small businesses to undertake and nurture. Both categories of innovations play a part in building a country's productivity and competitiveness, but are likely to be supported in different ways.⁴⁴

Putting all of the above concepts of the R&D process together, it seems that large, established firms will have a higher likelihood of reaping the benefits from sustaining R&D than from disruptive R&D. That some innovations are disruptive is one of the reasons that small businesses play a dynamic role in the growth of new businesses, but also in the R&D that gets done. William Baumol observes that "older firms organized appropriately for one generation of technology may find that the same organization handicaps their use of newer technologies."⁴⁵ But Dr. Baumol's analysis indicates that there are broader systematic reasons for large businesses being more risk adverse in their R&D activities and thus focusing more on incremental changes and improvements.⁴⁶ This systematic risk aversion may require an extra incentive to promote the increased investment in riskier basic research.

In 2007, NSF estimates that 19 percent of all R&D was performed by businesses with 5 to 499 employees. While they do not perform the largest amount of R&D among private sector companies in absolute terms, an impressive 85 percent of small business funding came from non-Federal sources, including their own sales, profits, etc. and they were one of the most R&D intensive size groups with non-Federal funding equal to almost 8 percent of sales compared to just over 3 percent for the economy as a whole. Small firm patents tend to outperform large firm patents using measures such as close link to research, originality and generality.⁴⁷ About 11 percent of manufacturing R&D is performed by small firms and about 40 percent of the technical and scientific services' R&D that

⁴⁴ There is no good measure of these different categories of innovations. U.S. patents are divided into utility and design patents. A utility patent can be for either a product or a process, large or small. A design patent applies to the ornamental design of a functional product, but the same product may have a utility patent or patents associated with it as well. In 2008, utility patents made up approximately 86 percent of the total granted in the U.S., with slightly over half of those granted to foreign entities.

⁴⁵ Baumol, W. "Small Firms: Why Market-Driven Innovation Can't Get Along Without Them," Chapter 8 of *Small Business Economy 2005*, Small Business Administration's Report to Congress.

⁴⁶ This is not to say that such methods cannot produce dramatic innovations over time. The large semiconductor manufacturers have driven several generations of improvements through steady incremental, but continuous changes to their products.

⁴⁷ Breitzman, A. and D. Hicks. *An Analysis of Small Business Patents by Industry and Firm Size*, Small Business Administration Office of Advocacy, November 2008.

often supports manufacturing R&D is performed by small businesses.⁴⁸

Furthermore, small companies employed 24 percent of the scientists and engineers employed by companies in the U.S. This outcome highlights a link between small business entrepreneurship and the U.S.' role in educating foreign born engineers and scientists. A recent Kauffman Foundation study found that for 25 percent of the technology firms founded between 1995 and 2005, the chief executive or lead technologist was foreign born. Over half of the

About 11 percent of manufacturing R&D is performed by small firms and about 40 percent of the technical and scientific services' R&D that often supports manufacturing R&D is performed by small businesses.

company founders had originally come to the United States as students and 40 percent originally came to work for someone else. The semiconductor industry had the largest percentage of foreign-born founders, 35 percent, followed by computers/communications, software and innovation and manufacturing-related services. These foreign-born start ups were also a significant part of technology clusters, with almost half of the start ups in Silicon Valley fitting this category, about a third of start ups in Boston

and San Diego being headed by foreign-born individuals, and close to 20 percent of the start ups in Research Triangle fitting the bill.⁴⁹

The financial meltdown has reduced available funding for all small businesses.⁵⁰ That makes it more important for the sources of government funding to remain active to support small business development. One of those programs, the Small Business Innovation Research (SBIR) program, was designed to provide grants to businesses for the specific goals of stimulating technological innovation and increasing private-sector commercialization of innovations derived from federal R&D.⁵¹ A multi-year reauthorization of the program is under discussion by Congress. NIST's Technology Innovation Program (TIP) also supports high-risk research with a focus on ideas with a strong potential for advancing state-of-the-art and contributing to U.S. science and technology base.

D. Human Capital Shortages in U.S. Fuel Offshoring

One of the important reasons for encouraging U.S.-trained scientists to stay in the United States is because these students are a very high percentage of the available talent produced by U.S. universities in the scientific fields. An NSF study shows that in 2007, almost 43 percent of the 31,801 students awarded science and engineering doctorates were non-U.S. citizens, a 6 percent increase from the previous year. The rate of increase of U.S. citizens receiving such degrees was 3.6 percent.⁵² While some of these students stay in the U.S., others return to their own countries to work.⁵³ The rate at which we produce and

⁴⁸ The small business (500 employees or less) share of GDP in manufacturing was 33 percent according to the latest analysis for 2004. It had risen from 1998 despite the decline in the manufacturing share in the all industry total. It may have risen further given the downsizing of larger producers. For an analysis of 1998-2004, see *Small Business Share of GDP, 1998-2004*, by Kathryn Kobe, SBA Office of Advocacy, April 2007.

⁴⁹ Wadhwa, Vivek. "Foreign-Born Entrepreneurs: An Underestimated American Resource," *Kauffman Thoughtbook 2009*, the Ewing Marion Kauffman Foundation.

⁵⁰ While venture capital provides only a small portion of small business financing, it is one indicator of the availability of funds for small businesses. Venture capital fell about 9 percent between 2007 and 2008 and was down over 50 percent during the first half of 2009 when compared with the same time period in 2008. "Venture Capital Investments 2Q 2009," National Venture Capital Association, July 21, 2009.

⁵¹ Testimony of Kesh S. Narayanan, NSF, before the Small Business Committee of the House of Representatives, April 22, 2009.

⁵² Falkenheim, J. and M Fiegenger. "2007 Records Fifth Consecutive Annual Increase In U.S. Doctoral Awards," *NSF Info Brief*, NSF 09-307, November 2008.

⁵³ A study of foreign-born founders of high-impact, high-technology firms in the United States found that a higher percentage of them had doctoral degrees than did similar firms founded by U.S.-born entrepreneurs. Most of the foreign-born founders are now U.S. citizens and two-thirds received their highest level of education in the United States. See Hart, D., Z. Acs and S. Tracy. *High-tech Immigrant Entrepreneurship in the United States*, Small Business Office of Advocacy, July 2009.

maintain highly skilled scientists and engineers would seem to be too slow.

The Battelle R&D survey finds that the leading incentive for offshoring has become a race for talent. In a recent announcement of its new research center in China, IBM Director of Research, John E. Kelly III, stated the “establishment of IBM Research in Shanghai reflects both the rich pool of science and engineering talent in China, as well as our continued commitment to expand our collaboration with Chinese enterprises and academic institutions.”⁵⁴ A BLS study scored 515 service-providing occupations according to a system that identifies the characteristics that make an occupation susceptible to being offshored. The majority of these were still considered unlikely to be performed overseas, but about 160 were considered offshorable. These occupations were quite diverse, with a wide range of job functions and educational attainment. However, one of the findings was particularly noteworthy in that “almost every computer and mathematical science occupation has some degree of susceptibility to offshoring.”⁵⁵

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were outsourced.*

These factors suggest basic industrial research could follow applied R&D offshore. That is in contrast to a decade ago when relatively lower tech development activities were outsourced. The conduct of drug trials and

computer program testing are major development areas accomplished abroad, largely for cost reasons. The remainder is sensitive to the availability of scientific talent, the shortage of which apparently is a worldwide problem.

There is an increasing amount of U.S. funded R&D being performed abroad.⁵⁶ In its recent article on R&D, Spectrum provided several reasons for such a shift.

There are a number of reasons why this shift of R&D work is happening now. First off, multinationals need to do research in the countries where they sell to adapt products to local markets, a practice known as localization. Indeed, segments of these local markets are approaching a scale that until now had been seen only in developed countries. Also, to gain market access they need to play along with the policies that local governments have instituted to modernize their countries, partly for the prestige of it and partly for the independence from foreign know-how that it promises to deliver. ... Finally, many of these investments were attracted by the lower costs of labor and capital in emerging economies. Workers in Google's Bangalore R&D center earn \$30,000, a royal sum there, but close to poverty levels in Silicon Valley. Government subsidies and tax policies often reduce the physical plant and land costs.⁵⁷

Denis Fred Simon, a professor of international affairs at Penn State University and expert on Chinese technology policy, identifies 1160 R&D centers in China that have been established by multinationals, an increase from 30 that existed in 1999. As leading examples of this trend “Simon singles out General Electric, whose Shanghai facility is doing world-class development of algorithms for three-dimensional medical imaging, and Intel, which is building a \$2.5 billion chip fab in Dalian, China.”⁵⁸

⁵⁴ IBM Opens New Research Center in China, IBM China Research Lab Expands Into Shanghai to Promote Collaborations and Scientific Exploration, IBM Press Release, October 14, 2008.

⁵⁵ Moncarz, R., M. Wolf, and B. Wright. “Service-providing occupations, offshoring and the labor market,” *Monthly Labor Review*, December 2008, pp. 71-86.

⁵⁶ BEA's statistics indicate that in 2006, the latest data available, about 16 percent of U.S. manufacturing multinationals' R&D is done in its foreign affiliates. Interestingly, about 16 percent of manufacturing R&D done in the United States is done by the U.S. affiliates of foreign companies.

⁵⁷ Hira, Ron and P. Ross. “R&D Goes Global,” *IEEE Spectrum*, November 2008.

⁵⁸ Id.

These findings coincide with those of the Boston Consulting Group and the NAM Manufacturing Institute which concluded:

Only those nations that continue to invest in innovation and its enablers, such as a highly skilled and talented workforce, will stay competitive in the long run.

R&D is the lifeblood of innovation and competitiveness and, thus, helps maintain the U.S. manufacturing industry's ability to compete worldwide. A skilled work-

force, in turn, is the lifeblood of R&D and the United States must meet the long-term demand for workers with math and science training to keep R&D in the U.S. However, R&D alone will not be effective in building the country's wealth and standard of living if it is the only part of manufacturing activities to remain in the U.S.⁵⁹ As can be seen above, R&D averages less than 4 percent of total sales and that direct spending is not a large part of GDP. Most of the benefit from R&D comes from the innovation-fueled improvements feeding back into a vital manufacturing base.

⁵⁹ Nonetheless, the UK, whose manufacturing share was about 13 percent in 2007, before the recession, is using an unusual approach in an attempt to raise its business and enterprise R&D intensity (BERD) from 1.1% of GDP to the E.U. target rate of 3 percent. It is undertaking a program whereby it is encouraging foreign businesses to partner with UK universities to conduct R&D. However, the weakness of this strategy is that once the R&D is completed the innovations it spawns many not benefit the UK.

V. Manufacturing Contributes More to U.S. Productivity Than Any Other Major Sector

R&D is only one step—albeit an important one—in the process of producing long-term income growth from the innovation process. Ultimately, R&D must be used to produce new or improved products or the same ones more efficiently if innovation is to make a country richer. Productivity is a key step in this process.

One simple analysis of the role of productivity was done by the OECD. It calculated the gap between the U.S. and individual OECD countries' per capita GDP in 2006. The gap was found to be almost totally explained by the differences in labor productivity. Norway and Luxembourg, which tended to have higher productivity levels than the U.S. also had higher per capita GDP. The countries that had a substantial negative GDP gap with the U.S. had much lower productivity levels.⁶⁰

The direct importance of the labor and multifactor productivity gains in manufacturing on the overall U.S. productivity growth and standard of living can be seen in Table 1. Manufacturing's labor productivity outpaced that of nonfarm business in all but the most recent time periods shown. During the period from 1995 through 2006, manufacturing labor productivity grew at a pace that was 1.5 percentage points per year faster than non-farm business overall. However, since 2006 manufacturing has not performed better than non-farm business and its productivity has lagged behind the rest of the economy during the recession.

The Bureau of Labor Statistics has calculated manufacturing's contribution to non-farm business' multifactor productivity (MFP) growth. During the period 1990-1995, manufacturing's MFP productivity accounted for virtually all of the growth achieved in non-farm productivity during that time period, with most of the productivity growth coming from the computer and electronic sector. In the most recent period measured, 2000-2006, the growth in manufacturing productivity has matched

that of non-farm business overall and manufacturing's contribution has slowed to about 35 percent of the 1.6 percent annual growth rate of non-farm MFP. That is still a substantial contribution from an industry that is becoming a smaller and smaller part of the overall economy.

One reason that manufacturing industries have traditionally produced faster productivity growth is they tend to be more capital intensive, using more capital to enhance labor productivity than is possible in many of the service sectors. However, in recent years, the rate of increase in capital service inputs to manufacturing has slowed dramatically, increasing only about 2 percent between 2000 and 2006.⁶¹ In contrast, the overall economy has increased its use of capital inputs by more than 2 percent per year during that period as more and more sectors have computerized.⁶² While the steady decline in manufacturing employment somewhat confuses an analysis of capital-to-labor ratios, this slowdown in the growth of capital inputs to the manufacturing sector is another sign that the uncertainty surrounding manufacturing may be hindering its long-term growth potential by slowing plant and equipment investment.

In the past year, as the recession has taken hold, labor productivity in manufacturing has dropped. While manufacturers were cutting workforces, those cuts did not keep pace with sharply declining output. Labor productivity in manufacturing declined 2 percent from year earlier levels during the first half of 2009 before showing a strong jump in the third quarter. To the extent this is a short-run cyclical outcome, it hopefully will right itself as the recovery begins.

⁶⁰ *OECD Science, Technology and Industry Outlook 2008*, Figure 1.1, p. 19.

⁶¹ While manufacturing's capital-to-labor ratio has risen during this time period, it has been as much because labor inputs have fallen than capital inputs have increased.

⁶² This productivity is, of course, dependent on manufacturers producing the necessary capital equipment that fuels that service sector productivity growth.

Table I. Comparison of Multifactor Productivity Trends
(percent per annum)

	Private Nonfarm Business	Manufacturing	Manufacturing's Contribution to Business Productivity (in percentage points)
1987-90			
Multifactor Productivity	0.5	0.2	0.06
Output per hour of all persons	1.5	1.8	
Contribution of Capital Intensity	0.6	0.3	
Contribution of Labor Composition	0.4		
1990-95			
Multifactor Productivity	0.5	1.2	0.55
Output per hour of all persons	1.6	3.4	
Contribution of Capital Intensity	0.6	0.4	
Contribution of Labor Composition	0.5		
1995-2000			
Multifactor Productivity	1.1	2.0	0.8
Output per hour of all persons	2.5	4.6	
Contribution of Capital Intensity	1.2	0.7	
Contribution of Labor Composition	0.2		
2000-2006			
Multifactor Productivity	1.6	1.6	0.57
Output per hour of all persons	2.7	3.8	
Contribution of Capital Intensity	0.9	0.6	
Contribution of Labor Composition	0.2		
2006-2008			
Multifactor Productivity	0.7	n/a	
Output per hour of all persons	2.2	2.0	
Contribution of Capital Intensity			
Contribution of Labor Composition			
2008 (Q1-3)-2009 (Q1-3)			
Output per hour of all persons	2.4	-0.5	

Source: Bureau of Labor Statistics

However, for the U.S. to stay competitive in world markets, the manufacturing sector must once again become a productivity leader for U.S. industry. To do this, the sector must have enough cash flow and confidence in its future to make the necessary long-term capital investments.

There are some other measures of manufacturing efficiency that are of longer run concern when considering the place manufacturing will have in the economy going forward. A recent study by MIT professor Timothy Gutowski, financed by the National Science Foundation, shows that newer manufacturing techniques tend to use more energy than some of the older techniques.⁶³ The energy use for the manufacture of semiconductors, carbon fibers and other new technologies is comparatively much higher than many of the manufacturing techniques associated with older technologies, such as smelting metals. Thus, as the manufacturing landscape shifts toward relatively more production of the high-technology goods, there is a greater use of energy. This is not an example of inefficiency in the U.S. manufacturing industry alone, but rather identifies inefficiencies in the manufacturing techniques that are used in these new industries. It is also a prime example of where process innovation can be extremely important. The relatively small process innovations that will eventually reduce the inefficiencies in these newer manufacturing techniques will make the producer more productive and more competitive within the worldwide production of these products. Consequently, the small incremental improvements that take place as a manufacturer learns by doing will be very important in determining who will be the low cost producers of these high-tech products. This research is one example of where government funding can help to provide a framework for determining where the next R&D dollars spent might provide beneficial gains to the producer and to the economy as a whole.

While U.S. productivity trends are on a worrisome path, at least in the short term, Europe still looks to the U.S. to provide insights into how to improve its own pro-

ductivity. Recent research in the European Union confirms earlier U.S. findings of Griliches and others that there is always a positive and significant impact of R&D on a firm's productivity even if there is not as strong a relationship between R&D and company profits or market valuation.⁶⁴ A second important finding from this European research is that R&D's impact is important, but different in companies in high-tech industries (those with high R&D intensities) compared to companies in low- and medium-tech industries. Overall an increase of 1 percent in the "stock" of R&D increased firm productivity by about 10 percent, but that ranged from 3-5 percent for low-tech industries to 14-17 percent for companies in high-tech industries. But, growth in a company's capital stock boosted productivity growth by 12-13 percent, almost all of it in the low and medium-tech industries.⁶⁵ This implies that "embodied" technological change which comes from the use of more advanced capital goods (and probably improved worker knowledge to use it) is a vital pathway in capturing innovation's productivity-enhancing value from the initial R&D investment. It also shows that innovation can flow to all parts of manufacturing, not just the few industries where R&D is highest. Lower tech industries benefit from advances in machinery and equipment produced in higher tech industries that perform significant R&D.

The importance of turning innovation into productivity growth is illustrated by Japan. Twenty years ago, Japanese manufacturing showed the world how to create quality products in an increasingly efficient and profitable manner. Interestingly, much of the impetus to develop these techniques began in the 1950s when Japanese auto manufacturers were focused on improving their productivity to match that of the U.S. at that time.⁶⁶ Many of the kaizen or "continuous improvement" processes it developed, such as cutting the costs of carrying inventories through just-in-time systems, were adopted worldwide. Japan is still one of the top investors in R&D in the world.⁶⁷ Yet, that alone has not been enough to overcome some of the other

⁶³ Chandler, David. *Manufacturing Inefficiency*, MIT Tech Talk, March 18, 2009.

⁶⁴ *R&D and Productivity: Testing Sectoral Peculiarities Using Micro Data*, by R. Ortega-Argiles, L. Potters and M. Vivarelli, Institute for Prospective Technology Studies working paper no. 03/2009.

⁶⁵ *Is Corporate R&D Investment in High-Tech Sectors More Effective?*, by R. Ortega-Argiles, L. Potters and M. Viarelli, Institute for Prospective Technology Studies working paper no. 09/2009.

⁶⁶ *The Miracle: The Epic Story of Asia's Quest for Wealth*, by Michael Schuman, Harper Collins, 2009, pp. 196-198.

⁶⁷ In 2007 Japan had an R&D intensity of 3.4 percent of GDP, higher than the U.S.' 2.6 percent.

problems facing its economy and it has experienced poor growth over the past decade. One of Japan's major problems in improving its growth rate is a shrinking workforce, and this is not a problem the U.S. is likely to experience to the same extent as Japan in the near future. On balance, the U.S. is more open than Japan to encouraging foreign talent to work in its economy.

Another issue in the Japanese economy is that high labor productivity in manufacturing is not spilling over

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into the service sector. This is partly due to structural rigidities in the Japanese system that are not present in the U.S. system. For example the OECD cites "weak ties between the business sector and research organizations in the public sector" and "low levels of openness to international trade and investment and of international R&D linkages" as hindering knowledge flows.⁶⁸

However, there is another of Japan's recent economic experiences that is very relevant to the U.S. and may sound a warning about policy actions that do not directly involve manufacturers, but could have a big impact on their long-run viability.

At the beginning of 1990, stock prices plummeted, followed by sharp declines in real estate prices. This

marked the start of major economic recession (collapse of the bubble economy). Japan's financial and economic systems, which were excessively dependent on land, consequently approached collapse. Huge bad debts were created in the loan portfolios of financial institutions because corporate borrowers suffered serious losses due to declining land prices. As a result, shareholders' equity in financial institutions shrank. In 1997, large banks began to fail ... Due to reluctance on the part of financial institutions to grant loans under efforts to improve their capital-to-asset ratio, the number of corporate bankruptcies in fiscal 2001 rose to the second highest level posted in the post-war period, following the record high registered in fiscal 1984. Furthermore, troubled by cash flow problems and lack of demand, companies were forced to cut employment and investments in plant and equipment.⁶⁹

The inability of Japanese banks to lend restricted credit flows to the economy is the primary source of Japan's prolonged period of low growth. The Japanese government was reluctant to encourage its banks to sell their bad debts or to otherwise facilitate their removal from balance sheets. This lack of liquidity prevented the banks from making new loans. The reluctance of the government to put pressure on the banks is a result of the debt-of-gratitude owed the banks for their financing of the export-driven policies Japan has pursued.⁷⁰

Policy makers need to learn from this and make sure the United States does not follow the Japanese experience by allowing the banking system to be bogged down by bad debts for years to come. The lack of access to capital at reasonable cost rates would mute a rebirth of needed economic activity and stifle the innovative process.

⁶⁸ OECD Science, Technology and Industry Outlook 2008, p. 132.

⁶⁹ Statistical Handbook of Japan 2008, Statistics Bureau of Japan, Chapter 3, p.26.

⁷⁰ Those policies also created inefficiencies in the domestic economy by promoting over-investment in key export sectors and protections to shield the domestic economy from foreign competition. Schuman (2009), pp. 211-213.

VI. The Face of Manufacturing Going Forward

The U.S. provides the largest market in the world for manufactured goods; consequently, manufacturing must continue to play an important role in the United States economy because the U.S. is not in a position to import all the manufactured goods that consumers and businesses require.

However, this recession has significantly changed the face of U.S. manufacturing and it is not entirely clear what it will look like in the future.

A. The Classification of Manufacturing

The definition used to circumscribe manufacturing has a significant affect on the data used to analyze the sector and the conclusions drawn about it. Most obviously, the share of manufacturing in the U.S. economy and the sector's multiplier impact depend on the way manufacturing is defined. To assess what tomorrow's manufacturing activities will encompass, it helps to consider its current definition and the classification it yields.

The unit of observation by which manufacturing is currently classified in the North American Industrial Classification System (NAICS) limits one's analytical vision.⁷¹ NAICS is based on the establishment as the locus of production activity. In today's world the establishment no longer has that exclusive distinction. Most production still takes place in a plant, but increasingly there may also be production in places like the home (telecommuting), space (satellites that move data) and on rooftops of homes and buildings (solar panels).

Currently, establishments in the manufacturing sector are defined for U.S. data collection purposes as those whose "activities are the mechanical, physical or chemical transformation of materials, substances or components into new products." This definition is not rigorously applicable for classification purposes.⁷² If anything, it is too narrow. That is not only for the reasons cited above, but also because manufacturing takes place in many tradi-

tional establishments assigned in government statistics to other major industrial sectors.

For example, some former manufacturing establishments were moved out of the manufacturing sector when NAICS replaced the SIC, such as the publishing industry, which was moved to the new information sector. So, too, were manufacturers' R&D labs, if they were at separate locations. The 1997 Census reclassified approximately 700 auxiliary manufacturing R&D establishments to the services sector when the change was made from SIC to NAICS. But where not separate, the R&D inputs are included in the sector which makes it difficult to separate them from the other inputs used in the main activities of the sector.⁷³

However, there is a broader concept of classification which was considered during research leading up to the development of NAICS, but has never been fully explored. In a seminal article T. P. Hill makes a distinction between services affecting goods and services affecting persons.⁷⁴ This distinction is useful because the service sector, as defined, must be disaggregated or it is so large it defies meaningful analysis. While NAICS took one step forward by disaggregating one very large service sector into several smaller ones, the ultimate decisions about the structure of the NAICS system did not lead to the most helpful disaggregation for thinking about industrial structure and competitiveness policy.

Consideration of services affecting goods reveals the demand generated by manufacturers outside their own sector. Some services to goods producers, such as the legal, accounting and scientific, are labor intensive. Others, such

⁷¹ OMB first adopted NAICS in 1997.

⁷² Manufactured products are easier to discern than manufacturing establishments, which usually produce a number of products and, often, some services.

⁷³ The new NSF R&D survey should facilitate more separation in the future.

⁷⁴ T.P. Hill, "On Goods and Services," *Review of Income and Wealth*, 23 December, 1977, pp. 315-338.

as distribution networks, like freight transportation, are more capital intensive.⁷⁵ The classification is not so much about what label to put on activities as it is about the data that are collected about a sector and the transparency with which linkages are revealed to enhance analysis. A different classification structure could help in analyzing the “manufacturing sector.”

Energy production and use are intrinsically partnered with environmental policy. Consequently, to improve the analysis of those issues it helps to think about energy grouped in a different manner than it is in NAICS. For example, the generation of electricity, gas, steam and water are classified in the utilities sector along with transmission and distribution which are essentially infrastructure.⁷⁶ Generation facilities sell their products to various distributors and are not unlike manufacturers. If they were part of manufacturing, the identification of sectors involved in achieving energy independence, for example, would be facilitated since already many of elements of alternative energy are classified in manufacturing. Oil and natural gas

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extraction and electricity generation are not, as activities or commodities, found in one classification category. They should be found in the same category as petroleum refining, ethanol production, wind turbines and solar panels.

To see the future of manufacturing, one needs to look at product totals—electricity, computers, etc. It is also necessary to do that in order to properly see how R&D dollars are allocated and where they should be allocated to create products that can be sold both here and abroad. The demand is for products, not establishment level output.

Classification by commodities has another important use. The E.U. is using it as the way to track material consumption for analysis of energy utilization and environmental pollution. The entire analysis uses data for material inputs to production, consumption and trade among E.U. countries, classified by commodity, not establishment. The analysis then tracks energy use and pollution effects by the product and in what E.U. member country it is produced.⁷⁷

B. Issues for the Future

Older industries will continue to play an important role in U.S. manufacturing, although some of them will contract, reinvent themselves or integrate horizontally. But, to stay globally competitive, new industries will have to emerge. This process is not unique to this historical period, but rather is intrinsic to the description of manufacturing as “creative destruction.”

Scenarios for the composition of output in the manufacturing sector of the future abound. Many include advances in health sciences, health care efficiencies, nanotechnology and other frontiers of physical sciences. These and others are undoubtedly going to offer new areas of research for manufacturers. But research into energy technologies is likely to provide future innovation and growth possibilities across many sectors of the economy.

Two important economic forces are moving toward changing the relative cost of energy in the coming decade. Those changes will encourage efficiencies and drive increased research throughout the economy over the next few years. The first is the increased global demand for energy which resulted in a rapid run-up in energy prices during 2007-2008, the third such disruptive price spike in less than forty years. This price spike has focused the U.S. on its dependency on foreign supplies of oil and the havoc such dependency creates for factoring energy prices into long-term investment decisions. That has brought a heightened urgency for the use of a wider range of energy sources and technologies.

The second force is the steady increase in greenhouse gas emissions around the world. The nations of the world

⁷⁵ For a further discussion of a different framework see Popkin, Joel. "An Alternative View of the Behavior of Industrial Output," (with K. Kobe) *Survey of Current Business*, U.S. Bureau of Economic Analysis, November 1993, pp 50-56.

⁷⁶ This treatment is a relic of the dominance of regulated utilities for which data were collected from administrative records.

⁷⁷ Helga Weisz et al. "The physical economy of the European Union: Cross-country comparison and determinants of material consumption," *Ecological Economics*, Vol.58, No. 4 (July 2006), pp. 676-698.

are in the process of negotiating a replacement for the Kyoto Protocol, and its mechanisms for reducing carbon and other greenhouse gas emissions, prior to its expiration in 2012. The United States will have to make decisions about its policies on carbon emissions in the very near future. Policy decisions are needed on both the methods by which the U.S. will reduce its carbon emissions and

The U.S. needs to maintain a longer-run view of which of today's manufacturing activities may provide the expertise and know-how to be the foundation for tomorrow's innovations.

how it will maintain U.S. firms' competitiveness as other countries make their own policy decisions in this area. Several U.S. states have already moved ahead on regulations to reduce greenhouse gas emissions in their state or region. However, adoption of a set of nationwide policies is crucial to investment planning and will make compliance easier for firms that have operations in multiple regions.

Using energy more efficiently will require innovation within the manufacturing process itself, but will also provide a market for manufactured products that will help reduce energy use for others. To those ends, manufacturers were already performing 67 percent of the \$5.7 billion of energy-related R&D taking place in 2007, and manufacturing companies were providing a large part of those funds. Only a small portion of the 2007 expenditures were for renewable energy research, but that share is likely to grow as more alternative technologies are researched and tested.

In 2002, the manufacturing sector generated 1.4 billion metric tons of carbon dioxide emissions related to its energy usage.⁷⁸ Over a third of that came from its use of electricity.⁷⁹ The Gutowski study, mentioned earlier, makes

it clear that developing more efficient energy use while maintaining our cutting-edge lead in high-tech industries will be of great importance in maintaining global competitiveness.

Work on producing electricity in the cleanest, safest and most cost-efficient manner possible will rank high among on the energy research priority list. One of the most abundant sources of energy with which to produce electricity in the United States and in the world is coal, but burning coal is also high in carbon emissions. Can R&D and innovation make coal a "better" fuel by finding the answers to carbon sequestration? Or will R&D and innovation point to a better energy technology? Research is progressing on both paths in search of the answers to these questions.

Many states are already focused on the important role that manufacturing will have to play in the "greening" of America and the potential jobs that may come from developing these new technologies. However, the U.S. will need to work hard to build and maintain world-class products using these new technologies because other countries are already making significant strides in R&D in some of these areas and are manufacturing the leading edge products. A recent article by Gary Pisano and Willy Shih in the *Harvard Business Review* argues that by focusing on "core competencies" and offloading successive low value-added activities, the U.S. has also lost or is in danger of losing:

Knowledge, skilled people and supplier infrastructure needed to manufacture many of the cutting edge products it invented. Among these are such critical components as light-emitting diodes for the next generation of energy-efficient illumination; advanced displays for mobile phones and new consumer electronics products, like Amazon's Kindle e-reader; the batteries that power electric and hybrid cars; flat-panel displays for TVs, computers and handheld devices; and many of the carbon fiber components for Boeing's new 787 Dreamliner.⁸⁰

The article goes on to make an example of the solar

⁷⁸ Schipper, M. *Energy-Related Carbon Dioxide Emissions in U.S. Manufacturing*, U.S. Department of Energy, November 2006.

⁷⁹ In addition, there are a few industrial processes related to specific manufacturing processes, such as making cement, that produce carbon emissions.

⁸⁰ Pisano, Gary and W.C. Shih. "Restoring American Competitiveness", *Harvard Business Review*, July-August 2009, p. 116.

panel industry, an industry with an important role in a renewable energy, lower-carbon emission future. However, the countries that are currently in the best position to make innovative strides in that sector are the ones with expertise in processing crystalline silicon and applying thin films of silicon on to large glass sheets, techniques that have been perfected in semiconductor and TV and computer display manufacturing.⁸¹ These are exactly the manufacturing activities that have been spun off to foreign companies as the U.S. moved to the “fabless” semiconductor business model. As a leader in R&D, the U.S. is clearly capable of being a leader in new cutting-edge, manufacturing technologies. But in a competitive race with a wide range of other countries, the U.S. needs to maintain a longer-run view of which of today’s manufacturing activities may provide the expertise and know-how to be the foundation for tomorrow’s innovations. To do that, the government needs to continually monitor science and technology development and publish timely reports and updates warning industry about competitive changes. The OECD does this for its members and some non-members, but it needs to be done from a U.S. perspective.

Another characteristic of manufacturing in the future will be collaboration among companies in R&D and production. Such collaboration efforts are facilitated by clustering. The importance of clustering especially in enhancing spillover potential has been discussed. Prime policy makers in clustering have been state and local governments, but their ability to carry out these functions has been hampered as the recession has cut into their budgets. The best of their policies need to be considered in a broader policy forum.

Finally, supporting some of the planned innovations produced by the manufacturing sector may require substantial investment in infrastructure in order to provide the base for the markets to grow. Without a substantial overhaul of the electricity grid, for example, many think that widespread use of the plug-in electric car will not be possible.⁸² Without maintaining the highway and rail systems, the transportation of future goods to domestic and foreign markets will not be possible in a cheap and efficient manner. Without widespread broadband access, the leading edge electronic goods will be produced in countries that have a larger base to support them. These infrastructure investments are supported by broader policy goals, which once set, provide a framework within which decision makers can move forward. Once the United States makes commitments to reducing carbon emissions, energy independence or providing broadband access to everyone, it has provided a future template for the next round of investments and innovative activities that will help achieve those goals.

⁸¹ Pisano and Shih, p. 118.

⁸² Others argue that without the creation of a smart grid to make electricity use more efficient, an increase in electric car production would require the building of more coal-powered electric plants which could offset carbon-savings from cars by creating more carbon emissions from power plants.

VII. Summary and Policy Recommendations

A. A Unique Opportunity to Regenerate The U.S. Manufacturing Base

The worldwide trauma surrounding this severe recession offers a unique opportunity to reverse the dire course the U.S. manufacturing sector has been on since at least the early 1980's. The industry's base here has been bruised by a series of international competitors starting with Japan, then the "young tigers" of East Asia and, finally, by China. But those countries are now facing competitive pressures and experiencing rising costs and slower productivity growth. Some of these pressures on foreign competitors have been surfacing for a while, at least as far back as the turn of the century. As noted earlier, the MAPI report analysis indicates cost advantages of some major foreign competitors is narrowing.

Meanwhile, U.S. manufacturing industries have accomplished difficult restructuring. They have been forced to make serious cost cuts, shut plants, shift product mix and introduce new products. Those factors will hopefully provide new productivity gains once output begins to grow again. Some have re-evaluated overseas outsourcing in response to supply chain failures and continued risk of intellectual property infringement. Those may now construct or renovate plants in the U.S. from which to satisfy domestic demand and devote more resources to export markets.

B. How Government Can Both Spur and Support Liftoff

In its 2004 report *Manufacturing in America*, the U.S. Department of Commerce concluded:

*Competing in a global market place puts a premium on government getting the economic fundamentals right to create an environment in which U.S. manufacturing can flourish.*⁸³

The role of government at this critical juncture is to abet liftoff. It must develop and implement policies that make U.S. manufacturing the envy of the world, just like Japan's manufacturing sector was twenty years ago. But unlike Japan, the U.S. has a more open economy. It can

and should grow and attract more scientific talent. It can continue to encourage and attract foreign investment. It can grow our domestic market and retain its foreign-born students by making immigration easier. It can intensify R&D to reassert U.S. leadership, by providing infrastructure and clustering that can make conducting R&D here more successful and profitable than elsewhere. Policies that promulgate reliable sources of energy for producers in the U.S. at stable prices, can have a sizable impact on U.S. production and attract foreign capital to produce here.

As proposed in the 2006 study, the broad path to achieving this renaissance is to elevate the banner "U.S. Production" to a higher level in the hierarchy of U.S. policy considerations. It is a positive beacon and does not require reversal of existing growth objectives of stimulating consumption, savings and investment. Policies that accelerate and strengthen manufacturing production in the U.S. will also stimulate those other three areas. Policies should strengthen manufacturing and maintain a level playing field for U.S. manufacturers to compete worldwide.

There have been many policies and specific actions recommended to enhance the muscle of the U.S. economy. Many are found in the list below provided they meet the test proposed here — does it directly support U.S. production?

- Reduce the burden on corporate income derived from production and sale of U.S. made products
- Invest in research and encourage business investment in research and development through three approaches:
 1. Government partnerships with business in applied research and development activities at a level at which business risk exposure is sufficient to insure adequate "market tests" of project viability.
 2. The new government initiative to identify basic research direction should be explored further to see if it produces useful metrics, and can be a guide for expanding private sector basic R&D.
 3. Assure businesses that the R&D tax credit availability can be relied on so projects with long gestation periods and riskier outcomes can be considered more frequently.

⁸³ *Manufacturing in America*, U.S. Department of Commerce, 2004, p. 30

- Make the policy commitments to develop cleaner, more efficient, more sustainable fuel technologies. The result will make the U.S. a very desirable location for production activity because the threat of spikes in energy prices will be substantially mitigated. It will also provide a clearer framework within which private decisions about research opportunities can be made. For example, once policy settles whether and how carbon will be priced in the marketplace, firms can factor that into deciding which innovative activities and investments make most sense.
 - Continue to improve our own education quality and accessibility to enhance our home grown pool of science and technology graduates and help in assuring foreign-born graduates that they have opportunities in the U.S. as well. In addition, support the programs of technical retraining that often are done at the community college level in order to smooth the transition of employees from one manufacturing industry to another.
 - Government at all appropriate levels should make infrastructure investment — transportation, communication channels and the energy grid — that:
 1. Promote the clustering of economic activity to, among other things, take advantage of R&D opportunities and enhance their potential through maximization of spillover potential.
 2. Take greater advantage of our oceans and hemispheric geographic endowment to encourage and maximize our edge as a place to produce for foreign markets.
 - Reconsider the scope and definition of manufacturing used by government statistical agencies.
 - While its industry composition has always been changing, the upstream industries that produce parts and components have emerged as a strong element. For companies to consider bringing the supply-chain home, this sector's health must be maintained so it can be relied on to supply, domestically, the parts and components on which finished goods rely.
 - A healthy number of U.S. small businesses have performed two vital functions exceptionally well. They serve as key niche providers for specialized manufac-
 - tured goods components and as incubators for R&D. U.S. small business policy should assure they remain vibrant. One step would be to widen the lowest corporate income tax bracket.
 - Stabilize the financial markets and work toward developing a system whereby non-performing loans can be written down and bank's balance sheets put in order for making new loans to businesses of all sizes. A fully functioning financial sector is vital for a vibrant manufacturing sector.
 - For reasons of both supply and demand, U.S. policy should facilitate a more strategic process for legal immigration.
 1. Mature industrial economies all face a slowing rate of population growth. U.S. policy should keep the door as wide open as possible to this source of talent and of demand for what U.S. produces.
 2. With scientific talent scarce, H-1B visa policy should be eased when demand for such human capital exceeds supply.
 3. Many of the foreign-born scientists and engineers trained and educated in U.S. universities will later become the entrepreneurs and business owners of the small businesses part of the high technology industries.
 - Follow a system of fairly-conducted trade that supports the expansion of U.S. manufactured exports using the international trading systems rules for governing a level playing field.
- U.S. manufacturers continue to step-up and meet the challenges of cyclical downturn and structural readjustment. Their efforts are beginning to show some successes. But to remain strong players in a competitive world will require continued focus on innovation and productivity gains, helped along by government policies that will smooth the path to success. This report and these recommendations are intended to be helpful in lifting the curtain on a resurgence of U.S. production that will bring with it the fruits of a higher standard of living for all Americans.

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