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US Manufacturing: Understanding Its Past and Its Potential Future†

Martin Neil Baily and Barry P. Bosworth

The development of the US manufacturing sector over the last half-century displays two striking and somewhat contradictory features: 1) the growth of real output in the US manufacturing sector, measured by real value added, has equaled or exceeded that of total GDP, keeping the manufacturing share of the economy constant in price-adjusted terms; and 2) there is a long-standing decline in the share of total employment attributable to manufacturing. These trends, going back several decades, are highlighted in Figure 1. Their persistence seems inconsistent with stories of a recent or sudden crisis in the US manufacturing sector. After all, as recently as 2010, the United States had the world's largest manufacturing sector measured by its valued-added and, while it has now been surpassed by China, the United States remains a very large manufacturer.

On the other hand, there are some potential causes for concern. First, though manufacturing's output share of GDP has remained stable over 50 years, and manufacturing retains a reputation as a sector of rapid productivity improvements, this is largely due to the spectacular performance of one subsector of manufacturing: computers and electronics. Meanwhile, the 90 percent of manufacturing that lies outside the computer and electronics industry has seen its share of real GDP fall substantially, while its productivity growth has been fairly slow. Complicating the

■ *Martin Neil Baily is a Senior Fellow in the Economic Studies Program and the Bernard L. Schwartz Chair in Economic Policy Development, while Barry Bosworth is a Senior Fellow in the Economic Studies Program and the Robert V. Roosa Chair in International Economics, the Brookings Institution, Washington, DC. Their email addresses are mbaily@brookings.edu and bbosworth@brookings.edu.*

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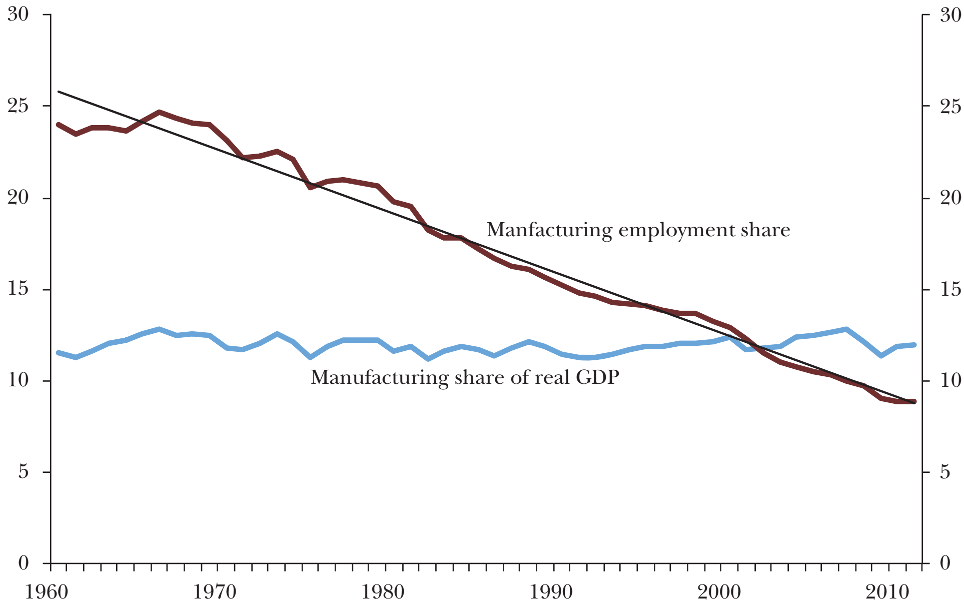
Figure 1
Manufacturing Value Added and Employment as a Share of the Total US Economy, 1960–2011
(in 2005 prices)



Source: Industry Accounts of the Bureau of Economic Analysis.
Note: Output is measured as value added in 2005 prices, and employment is reported as persons engaged in production (full-time equivalent employees plus the self-employed).

matter, the data on output and purchased inputs suffers special measurement issues, raising questions about whether real output and productivity growth are overstated.

Second, although manufacturing's *share* of total US employment has declined steadily over the last 50 years (see Figure 1), recently there has been a large drop in the absolute *level* of manufacturing employment that many find alarming. After holding steady at about 17 million jobs through the 1990s, manufacturing payroll employment dropped by 5.7 million between 2000 and 2010. In large measure, the explanation lies with the equally striking decline of employment in the economy as a whole during the Great Recession and its aftermath, but the size of the absolute job loss deserves further examination.

Third, the US manufacturing sector runs an enormous trade deficit that had already reached $316 billion by 2000, hit $542 billion in 2005, and remains very high despite the recession, equaling $460 billion in 2012; the manufacturing deficit is also very concentrated in trade with Asia, which represented over three-quarters of the deficit in 2000 and more than 100 percent in 2012. In 2000, only about one-third of the large deficit with Asia was accounted for by trade with China, but since then China has greatly increased its share, rising to 72 percent by 2012. The fall in manufacturing employment post-2000 has coincided with much of the growth in the bilateral trade imbalance with China, which suggests to some a causal link in which China trade is the reason for the loss of US manufacturing jobs. (And it may cause a feeling of *déjà vu* for those who remember the debate over trade with Japan in the 1980s and 1990s.) However, economists also recognize that trade imbalances are largely a macroeconomic phenomenon, reflecting the gap between national saving and domestic investment, so linking the trade imbalance to the problems of US manufacturing is more complex than blaming other countries.

In what follows, we examine each of these issues in greater depth and conclude with a discussion of the outlook for the future evolution of the manufacturing sector and its importance for the US economy. While US manufacturing remains an area of significant technological innovation, many of the largest US corporations continue to shift their production facilities overseas. It is important to understand why the United States is not perceived to be an attractive base for their production.

Trends in Manufacturing Output: Is It All about Computers?

Computers become faster and more powerful over time, implying large declines in their quality-adjusted prices.[1] Prices of computers, in this sense, do deflate in the ballpark of 10 or 20 percent a year. Thus we see much faster growth in the computer industry's real output than in its nominal output.

While the stability of the manufacturing share of *real* US GDP, highlighted in Figure 1, is striking, the manufacturing share of value added in *nominal* US GDP has fallen in half over the past half century—from about 25 percent in 1960 to 12 percent in 2010. The difference between these two perspectives is entirely due to the rapid fall in the quality-adjusted relative price of manufacturing output, which in turn is almost entirely driven by the fall in the quality-adjusted prices of computers and electronic products (Houseman 2012).

Pricing Computers

We have consistent industry-based data back to 1987, and over the 1987–2011 period, real value added in manufacturing expanded at almost the same rate as GDP as a whole, 2.6 as opposed to 2.5 percent per annum, as shown in Table 1. The exclusion of the computer and electronics industry, however, reduces the annual growth rate of US manufacturing output during these years to 0.6 percent. Even though the computer and electronics industry represented only about 10 percent of nominal value added in manufacturing, its real growth rate averaged nearly 20 percent annually—30 times that of the rest of the US manufacturing sector—and so its effects

[1] As an example, let's say that the price of one's new computer is the same as the price of one's old computer, but the new computer is four times better. Although the nominal price of the new computer is the same, in real terms, the new computer is only .25 times the price of the old computer.

Table 1
Annual Rates of Growth in Value Added of the US Manufacturing Sector and Growth in GDP, 1987–2011
(percentage change)

	1987–2011	*1987–2000*	*2000–2011*
Gross Domestic Product	**2.5**	**3.4**	**1.6**
Manufacturing	2.6	3.8	1.2
Manufacturing less Computers	0.6	1.5	–0.4
Durable Goods	4.0	5.4	2.5
Durable Goods less Computers	0.6	1.5	–0.5
Computers and Electronic Products	19.5	23.5	15.0
Nondurable Goods	0.7	1.4	–0.3

Source: Industry Accounts of the Bureau of Economic Analysis and authors' calculations.

on the growth of the overall manufacturing sector are dramatic. Table 1 also shows that the growth rate of production in durable goods as a whole averaged 4.0 percent annually from 1987 to 2011, comfortably exceeding the 2.5 percent annual rate of real GDP growth. But again if one looks at the growth of durable goods output while excluding computers and other electronics products, it is only 0.6 percent per year over this time. In short, outside of the computer and electronics industry, there is a clear decline in manufacturing's share of real GDP.

The measures of value added for the computer and electronics industry are heavily influenced by adjustments for the improved quality of these products. The measures are constructed by the Bureau of Economic Analysis within an input-output framework that provides nominal values for gross output of the industry, purchases of intermediate inputs, and value added. Indexes of the prices of gross output and intermediate inputs are assembled from the price index programs of the Bureau of Labor Statistics. The growth of real value added is the growth of gross output minus the growth of inputs, weighted by the nominal share of inputs in gross output.[2]

The relevant estimates of value added and its derivation in the computer and electronic products industry are summarized in Table 2. It is notable that the industry has expanded at relatively modest rates in nominal terms. Meanwhile, the rapid growth of real value added in the industry has been driven by the large declines in the quality-adjusted price index of its gross output. The nominal magnitude of purchased inputs has varied over time, but the prices of inputs have only slowly trended down: that is, the data imply that the rapid pace of innovation in computers and electronics is centered *within* the industry (not in the purchased inputs). Because value added has typically represented less than half of gross output, percentage changes in gross output imply even larger changes in value

[2] More specifically, the price of value added is an implicit price obtained from the ratio of the nominal and real values.

Table 2
Output Trends for the US Computer and Electronic Products Industry, 1987–2011

	Billions of dollars		
	1987	*2000*	*2011*
Value added	85.1	172.1	227.0
Gross output	216.4	503.6	350.1
Purchased inputs	131.4	331.5	123.1
Exports	18.8	55.5	48.4
Imports	14.8	89.8	119.7
Trade balance	4.0	–34.3	–71.3
	Annual percentage rates of change		
	1987–2011	*1987–2000*	*2000–2011*
Nominal values			
Value added	4.2	5.6	2.6
Gross output	2.0	6.7	–3.3
Intermediate inputs	–0.3	7.4	–8.6
Real values			
Value added	19.5	23.5	15.0
Gross output	9.0	15.4	1.8
Intermediate inputs	1.7	11.1	–8.5
Price indexes			
Value added	–12.8	–14.5	–10.8
Gross output	–6.4	–7.6	–5.0
Intermediate inputs	–1.9	–3.3	–0.2

Source: Industry Accounts of the Bureau of Economic Analysis.

added. Hence, a 6 percent average annual rate of decline in the price of gross output over the 1987–2011 period translates into a 13 percent rate of decline in the value-added deflator, and an extraordinary 20 percent annual rate of growth for real value added.

The domination of computers in the data raises some real concerns. First, it suggests that the seeming stability of manufacturing output (in value-added terms) may be more fragile than it appears, because it is being sustained by only a narrow part of the US manufacturing sector. Furthermore, this best-performing portion of manufacturing is rapidly moving overseas, and the United States now is a large net importer of computers and peripheral equipment, as shown in the top portion of Table 2. In two decades, the United States transitioned from being the global leader in producing computers to one among many players. That elevates the concern with sustainability. Second, while the technological advances within the computer industry contribute importantly to improvements in living standards through the expansion of computer services and the fall in their price, they may not raise the competitiveness of American workers because they can be incorporated with equal ease into foreign or domestic production of computers.

Input Price Bias

Another issue that arises with respect to the measurement of value added in the manufacturing industry is a concern that its growth may be overstated because of possible biases in the estimates of material inputs coming from mismeasurement of the input price deflators. The issue was explored in this journal by Houseman, Kurz, Lengermann, and Mandel (2011) in the context of offshoring of purchased inputs. If a US-based manufacturer shifts its purchases of components from one foreign producer to another in order to get a lower price, the components from the new source are treated in the price statistics as different products from those purchased from the previous supplier and the drop in their price is ignored. In the US consumer price statistics, the parallel issue is called "outlet substitution bias": that is, if consumers are buying the same product at a lower-priced warehouse store rather than at a higher-priced seller, it is not treated as a price decline, because prices are followed on a same-store basis. This problem arises in the price statistics even if the buyer switches suppliers within the United States, but it becomes more important as American companies start buying more low-price components from Asia or Mexico. It affects the measures of value added because if the increase in the price index for purchased inputs is overstated, the corresponding estimate of the growth in the real value of the inputs is understated, and the resulting measure of value added is too high.

Houseman et al. (2011) estimate that the growth in real value added of the manufacturing sector is overstated by about 0.2 percent a year. Feenstra, Mandel, Reinsdorf, and Slaughter (2013) draw on the economics of variety from the international trade literature and give a more expansive analysis of biases, one which takes outlet substitution bias into account but also estimates the impact of the increased number of suppliers now available.[3] They consider the whole business economy, not just manufacturing, and estimate that growth in GDP (real value added) originating in this sector is overstated by about 0.15 percent a year. However, most of this bias occurs in manufacturing. We think their findings imply about 0.7 percent a year overstatement of real value-added growth in manufacturing, coming roughly half from outlet substitution and half from the impact of the greater variety of input sources. However, as Feenstra et al. stress, it should be remembered that these estimates of bias in the measures of value added may to some extent be offset by other biases elsewhere.

The biggest potential bias in the input price data is in the computer and electronics industry, as both Houseman et al. (2011) and Feenstra et al. (2013) emphasize. Starting after 1997, the output price index for this industry was changed

[3] They also look at the impact of changes in tariffs and how they are treated in price and quantity indexes. They say these policy shifts did induce a bias in import price indexes, but only a very small one.

Table 3
Productivity Growth in US Computers and Manufacturing, 1987–2011
(average annual percent change)

	1987–2011	*1987–2000*	*2001–2011*
Output			
Total Nonfarm Business	2.8	3.7	1.7
Manufacturing	1.7	3.5	−0.4
Computers	8.0	14.6	0.7
Manufacturing less Computers	0.8	2.0	−0.5
Labor Productivity			
Total Nonfarm Business	2.2	2.0	2.4
Manufacturing	3.3	3.5	3.0
Computers	10.6	15.2	5.4
Manufacturing less Computers	2.3	1.9	2.8
Multifactor Productivity			
Total Nonfarm Business	0.9	0.8	1.1
Manufacturing	1.3	1.2	1.5
Computers	9.7	10.3	9.1
Manufacturing less Computers	0.3	−0.1	0.7

Source: Authors' calculations based on data of the Bureau of Labor Statistics Division of Major Sector Productivity, http://www.bls.gov/mfp/mprdload.htm. See also, table 1 of Houseman, Kurz, Lengermann, and Mandel (2011).
Notes: Manufacturing industry data are based on gross output. Nonfarm business aggregates are based on value added.

from a "matched model approach," in which the prices of currently produced models are matched to similar models produced in the past, and shifted to an hedonic-based index, which seeks to estimate and quantify the quality change between models so that it can be counted as a rise in output. However, there was no corresponding shift in the methods used to construct the price index for inputs. The Bureau of Labor Statistics should take a hard look at its input price indexes and correct biases it can verify. However, multifactor productivity growth in the computer and electronics industry is estimated to be over 10 percent a year, fueled by the remarkable technological advances in this industry. Correcting the input price data and reducing estimated real value-added growth by roughly a percentage point will change the numbers, but it will not change substantially the basic story of the evolution of value added for the computer and electronics industry or for the rest of the manufacturing sector.

Productivity

The computer and electronics industry has a particularly large effect on evaluations of the productivity performance of the manufacturing sector. As shown in Table 3, labor productivity in total manufacturing advanced at an annual pace of 3.3 percent over the 1987–2011 period compared to 2.2 percent for the total nonfarm business economy. Similarly, multifactor productivity (MFP) appears to have grown more rapidly in manufacturing than in the overall business sector. Both of these outcomes seem very consistent with the popular view of manufacturing as a leading source of innovation and technological improvements. However, those beliefs appear to be driven in recent years by the performance of the computer and electronics industry, whereas the noncomputer manufacturing industries have rates of productivity improvement similar to or below the economy-wide average. As shown in the table, multifactor productivity improvements in the noncomputer manufacturing sector are particularly modest, averaging only 0.3 percent per year, compared to 0.9 percent for the overall business sector. However, capital–labor substitution and changes in the use of other inputs raise the rate of labor productivity increase to equal that of the nonfarm sector as a whole. In summary, the computer and electronics industry has a large impact on one's evaluation of the performance of manufacturing. This part of the sector has had tremendous quality-adjusted output and productivity growth, even allowing for data errors. In contrast, the noncomputer part of manufacturing has exhibited very slow output and multifactor productivity gains and only moderate labor productivity growth.

The Employment Decline in Manufacturing

The decline in manufacturing employment as a share of the economy-wide total is a long-standing feature of the US data and also a trend shared by all high-income economies. Indeed, data from the OECD indicate that the decline in the share of US employment accounted for by the manufacturing sector over the past 40 years—at about 14 percentage points—is equivalent to the average of the G-7 economies (that is, Canada, France, Germany, Italy, Japan, and the United Kingdom, along with the United States).

One explanation often given for this pattern is the "relative productivity hypothesis," which posits rapid relative productivity growth in manufacturing combined with unfavorable income and price elasticities. If output per worker rises more rapidly in one sector than in the rest of the economy, this will generally contribute to a fall in the relative price of that sector's output, which in turn will boost the demand for that sector's products. In addition, the overall increase in income in the economy as a whole coming from economy-wide productivity growth will add to sector demand. However, if the sector-specific price and income elasticities of demand are not large enough in absolute value, these sources of growth will not generate demand growth that exceeds the rate of productivity growth in that sector. The result is a trend decline in that sector's employment share. An appeal of the relative productivity hypothesis is that it could explain both the long-term trend decline in the manufacturing employment share in the United States and the fact that other advanced economies have seen the same pattern. Relatively rapid increases in output per hour and relatively low income and price elasticities could prevail both over many years and across countries. The evidence most often cited to support the relative productivity hypothesis is that labor productivity growth in manufacturing in the United States and in most other OECD economies has grown faster than overall labor productivity.[4]

The evidence on price elasticities is not as clear cut. When successful new products are introduced, the growth of demand can be very rapid if they achieve widespread acceptance. Once the market is "saturated," demand depends on the replacement cycle and growth slows. The introduction of the automobile before World War II is an example and so is electronics after the war. However, evidence from United States indicates that the manufactured goods share of the expenditure pie is falling over time measured in current dollars. Edwards and Lawrence (2013, table 3) document the fact that the share of consumption by Americans devoted to goods has declined from 50 percent in 1970 to 37 percent in 2000 and to 34 percent in 2010. Current-dollar US fixed nonresidential investment has also declined as a share of GDP since the 1980s (Baily and Bosworth 2013). (Note that the expenditure shares include manufactured goods purchased from overseas.)

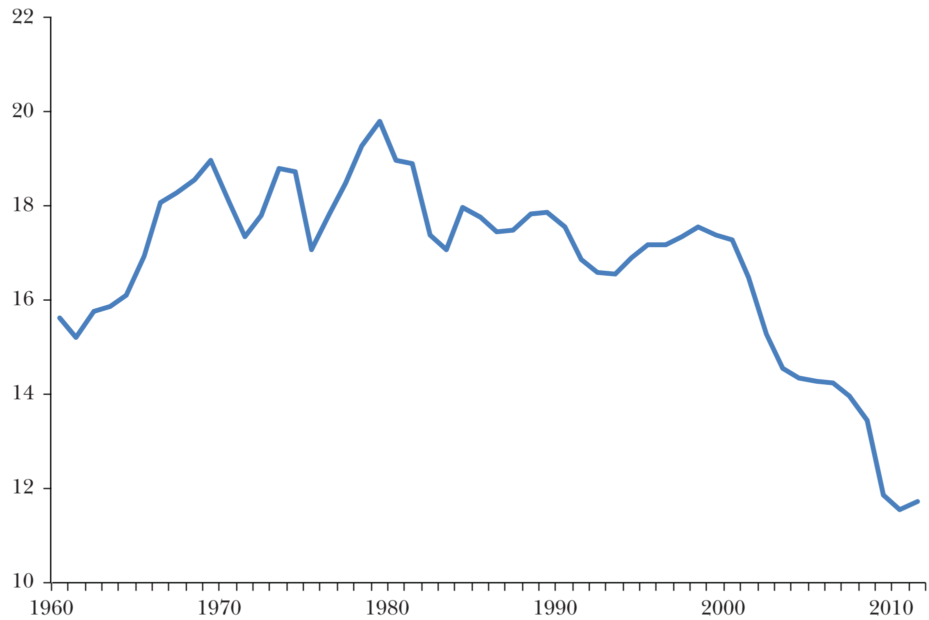
The relative productivity hypothesis runs into trouble, however, in explaining what has happened in the last 20 years or so. Productivity in the noncomputer segment of US manufacturing rose by 2.3 percent a year from 1987 to 2011 compared to 2.2 percent a year in the nonfarm business sector as a whole, as shown in Table 3. The labor productivity growth rates are the same, within a tenth of a percent. Whatever may have been true in the past or in other countries, the falling share of US employment in manufacturing excluding computers was not driven by excess productivity growth in 1987–2011. (In contrast, rapid relative productivity growth was important in the computer and electronics industry, where productivity growth was extraordinary.) The continued trend decline in the manufacturing employment share since 1987, therefore, was the result of the falling share of spending going to manufactured goods and the falling fraction of those goods that were produced in the United States.

The dramatic fall in the absolute level of US employment in manufacturing after 2000—a loss of one-third of the total by 2011—has been noted by many observers. It seems to conflict with Figure 1, which shows that manufacturing's employment *share* has been declining and continues to decline at a steady rate. By itself, the change in manufacturing employment, shown in Figure 2, certainly seems unprecedented. After remaining flat throughout the 1980s and 1990s, the total number of manufacturing jobs fell continuously in the 2000s. The largest decline is in computers and electronics, but the job losses are large in all of the underlying industries.

However, what is missed in a focus on a single sector is that job weakness after 2000 was not just a manufacturing issue; employment in the entire US economy went through a negative shift after 2000. Comparing the period 2000–2011 with

[4] The major source of international data on productivity is the Structural Analysis (STAN) Statistics of the OECD at http://www.oecd-ilibrary.org/industry-and-services/data/stan-oecd-structural-analysis-statistics_stan-data-en. Prior to its elimination in the 2013 budget cuts, the International Labor Comparisons program of the US Bureau of Labor Statistics also provided comparable international data. For instance, http://www.bls.gov/news.release/prod4.nr0.htm.

Figure 2
Persons Engaged in Production in US Manufacturing, 1960–2011
(millions)



Source: Industry Accounts of the Bureau of Economic Analysis.
Note: Persons engaged in production are measured as full-time equivalent employees plus the self-employed.

the period 1987–2000, we see that the average annual growth rate of total nonfarm employment slowed from 2.1 percent per year to –0.1—a deceleration of 2.2 percent per year—compared to a 3.3 percentage point deceleration in manufacturing.

After a sluggish recovery in the first couple of years after the 1990 recession, US aggregate demand started to surge as consumption grew rapidly, the technology boom spurred investment, and residential and commercial construction increased. Employment in all sectors was the beneficiary of this domestic demand growth, as actual GDP went well above potential GDP, according to the Congressional Budget Office. US manufacturing employment was sustained by the boom, remaining flat during the decade through 2000 despite rapidly increasing imports and a rising trade deficit (which reached $316 billion in 2000). After 2000, employment in the whole economy grew much more slowly and was ravaged in the Great Recession. Most major sectors of the economy experienced negative job growth or a substantial slowing, but manufacturing was among the hardest hit. Since 2000, there has been no significant change in relative rates of productivity growth between manufacturing and the total economy after 2000, so the relative decline of manufacturing employment is also reflected in output growth. Edwards and Lawrence (2013) attribute that outcome to a high elasticity of manufacturing output to fluctuations in aggregate demand. Others, however, point to increased import penetration as a major contributor (Pierce and Schott 2012).

The Role of Trade and the Importance of China

The US economy last achieved a balance of trade in manufactures in the early 1980s, and the size of the manufacturing trade deficit has grown steadily over time. In the mid-2000s, the size of the US trade deficit in manufacturing was equal in value to nearly half of manufacturing value added and is now equivalent to about 40 percent. Furthermore, the US deficit in manufacturing trade of $460 billion in 2012 exceeded the total current account imbalance of $440 billion. (The US economy has a surplus in services trade and records a positive and rising net inflow of income on its foreign investments, despite being a large net debtor.) These statistics are used to argue that the rising trade deficit—and in particular the trade deficit with China—is the primary cause of the sharp decline in manufacturing value added and employment after 2000. Pierce and Schott (2012), for example, link manufacturing employment loss to the granting of permanent normal trade relations to China in 2000. They report that "industries where the threat of tariff hikes declines the most experience greater employment loss due to suppressed job creation, exaggerated job destruction and a substitution away from low-skill workers" (quoted from the abstract). Autor, Dorn, and Hanson (2013) estimate that China's improved competitive position between 1991 and 2007 explained at least 25 percent of the decline of US manufacturing employment during that period, about 40 percent during the 2000s. Not everyone agrees that trade is important for the post-2000 employment decline. For example, Edwards and Lawrence (2013) point out that the trade deficit was already very large in 2000, and they estimate that the job content of the trade deficit in 2012 was very similar to what it was in 2000. They conclude that trade accounts for little of the fall in employment after 2000.

It is notable that for most of the past three decades, a growing trade deficit was associated with a buoyant domestic economy, rapid job growth, and a decline in unemployment to unprecedented levels.[5] This domestic strength suggests that the trade deficit was not something forced on the US economy by outside pressures, but rather a response to changing domestic economic conditions that pushed aggregate demand beyond the nation's productive capacity. The excess demand was satisfied in a noninflationary way by exporting less and importing more. This was reflected in turn by an increase in foreign financial investments in the United States coming from a rise of saving relative to investment in other countries, a large growth of supply capacity in countries that export to the United States, and a stable or rising value of the dollar. Many of the discussions of the role of trade on the evolution of the manufacturing sector ignore that macroeconomic context.

[5] Using the Congressional Budget Office's measure of potential GDP, the utilization rate for total GDP averaged 100 percent over the 1985–2007 period.

Table 4
US Balance in Manufactures Trade by Area, 2000–2012
(billions of dollars)

Item	*2000*	*2005*	*2012*	*Change 2005–2012*
Total	**–316**	**–542**	**–460**	**83**
Asia	–240	–372	–478	–106
China	–84	–206	–342	–137
Hong Kong	3	7	31	23
Other Asia	–160	–173	–166	7
Canada	–15	–16	46	62
Latin America	–3	–28	57	85
Europe	–58	–131	–128	3
Middle East & Africa	1	4	43	39

Source: US Department of Commerce, Bureau of the Census, "International Trade in Goods and Services, Supplementary Tables," various years.

Between the early 1980s and the end of the boom in 2007, Americans devoted ever-increasing shares of their incomes to consumption—the consumption share of GDP rose by 6 percentage points to 67 percent by the end. The surge of consumer spending was reflected in a substantial reduction in private saving. At the same time, the boom in information technology made the United States a particularly attractive location for business investment, and a strong expansion of residential investment contributed to the growing domestic imbalance between saving and investment.

These trends have large implications for manufacturing because it dominates the tradables sector of the economy: thus, the emergence of sustained trade imbalances will lead to major shifts in the size and composition of the domestic manufacturing sector. In the presence of sustained domestic demand, firms are often content to focus on domestic markets, and those that wish to increase their global sales will do so through the expansion of their overseas production facilities rather than exporting out of a fully employed domestic economy.

Of course, all of this has changed in the aftermath of the financial crisis. The United States is faced with considerable unemployment and may be stuck on a low-growth path for some time to come. With deficient domestic demand, it is now very interested in improving its trade performance as a means of reviving the domestic economy, but it is hard to reverse course in a weak global economy.

As shown in Table 4, the United States has typically had a large manufacturing trade imbalance with most regions of the world. The total has fallen from its peak in the mid-2000s, but the imbalance with Asia continues to increase. The deficit with China is particularly striking both in its size and its rate of increase in recent years. In general, economists prefer a multinational perspective on trade as opposed to an emphasis on the bilateral relationships, but over the past decade the magnitude of the US–China bilateral imbalance has reached extreme levels. China's trade surpluses reflect its own macroeconomic imbalances: an excess of national saving over domestic investment (even though both seem extraordinarily high by American standards).

It is instructive to divide China's trade regime into two distinct components, normal trade and processing trade, because the two have been evolving in different ways. About half of China's trade is accounted for by processing activities, which are based on the duty-free import of goods to be assembled and re-exported. The distinguishing features of processing activities are the low contribution of domestic value added and domination by foreign-invested enterprises (accounting for about 80 percent of output). In fact, China's processing trade is an integral part of a larger regional production network of companies in Asia, companies that had long exported to the United States and have now moved their assembly work to China. Morrison (2012) shows that US imports from the Pacific Rim countries, including China, have been a nearly constant share of US manufacturing imports since 1990, but that China's share of that trade rose from 8 percent in 1990 to 55 percent by 2011. The exports from these countries are widely diversified by recipient country, but the United States is the largest single destination.

The development of transnational production networks is but one of a series of profound organizational innovations that have given millions of poor unskilled workers—particularly in Asia—access to the global economy. Capital and technology are now mobile in ways they never were before, and both can move about the globe in search of the optimal combinations of skilled and unskilled labor and preferred institutional arrangements. The result has been an unprecedented growth of a global middle class. But those innovations have also introduced a rapidly changing set of circumstances for workers and firms in developed economies that are now exposed to much more intense global competition.

The distinction between the processing and normal trade components is important for evaluating the importance of trade as a driver in China's overall growth. China's trade sector is certainly oversized by the standards of other large countries; but, as highlighted in a recent paper by Koopman, Wang, and Wei (2012), the domestic value-added content of processing exports from China is much lower than that of normal exports. They used a detailed input-output table to estimate the foreign and domestic content of China's exports, and found a sharp contrast in the 1990s when the domestic content of China's processing exports was only about 20 percent compared to 90 percent for normal exports. The processing and normal trade exports have become more similar over time: the domestic share of China's processing goods has steadily grown as the foreign firms have increased their reliance on local sources for the components, and the domestic producers of normal exports have increased their use of foreign inputs. However, the domestic content of processing exports is still less than half that of normal exports.

China's normal (nonprocessing) trade has also grown very rapidly, and processing trade is actually a shrinking share of the total, falling from about 55 percent of the total in 2004 to about 44 percent in 2011 (based on data from China Customs). China's balance of normal trade has fluctuated over the years, and it has been in substantial deficit since 2008, as shown in Figure 3. As a result, processing trade currently accounts for China's entire trade surplus.

China's processing trade and the growth of the Asian production network are of particular importance to an understanding of the evolution of the US manufacturing sector. Many American firms have shifted away from the prior model of large integrated production units to focus on product design and marketing. They contract with firms that are part of the regional production network in Asia, and undertake little of their own production. For example, the US trade deficit in the computer and electronics industry rose from 14 percent of gross industry output in 1998 to 56 percent in 2011, and the industry accounted for 38 percent of all imports from China in 2012. Apple Inc. is a leading example of such a company: in recent years it has owned no large production facilities in the United States or elsewhere, preferring to contract with companies based in Taiwan and Korea who assemble the products in China (like Foxconn, for example). But by controlling key elements in the value chain, Apple extracts much of the profit. Similar networks have become common in the market for personal computers. In contrast, Mattel has also closed all of its production facilities in the United States, but continues to operate factories throughout Asia.

Most of the analysis of the US trade deficit with China has focused on the import side of the accounts. Yet measured as a share of the importing country's GDP, the magnitude of US manufactured imports from China is virtually the same as the magnitude of Europe or Japan's imports from China.[6] In 2010, imports from China accounted for 2.6 percent of GDP for the EU-15, 2.8 percent in Japan, and 2.7 percent for the United States. Instead, the differences in trade are on the export side, where exports to China account for only 0.8 percent of US GDP, compared to 1.2 percent for Europe and 3.5 percent for Japan. Given the historical antagonism between Japan and China, it is difficult to accept the view that China discriminates against the United States to a greater degree than Japan. Of course, Japan is closer to China; but, in a broader context, where we have used gravity equations to compare US, EU, and Japanese trade flows with a large number of trading partners, the US share of imports in GDP is normal, but its export share is consistently far below that of both Europe and Japan (Bosworth and Collins 2010).[7]

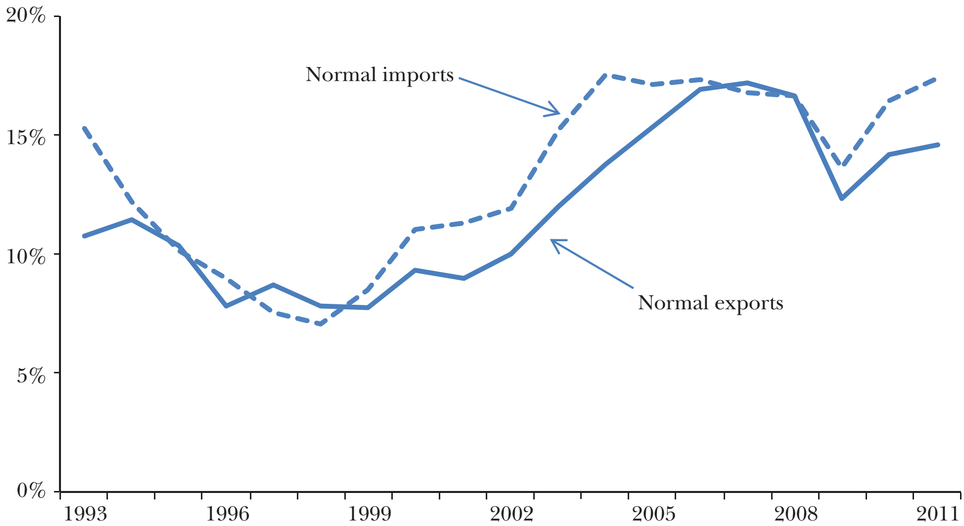
The United States is an important but not dominant export market for China. Exports to the United States were 20 percent of China's total in 2011, about the same as the US share of global GDP, but this was down from 29 percent in 2001. Furthermore, while China has a large trade surplus with the United States, many of its exports are in the processing sector where the value-added benefits to China are limited. On the export side, China is America's most rapidly growing market,

[6] To obtain a consistent classification, over time, we defined Europe as the aggregate of the original 15 members of the EU and excluded intragroup trade.

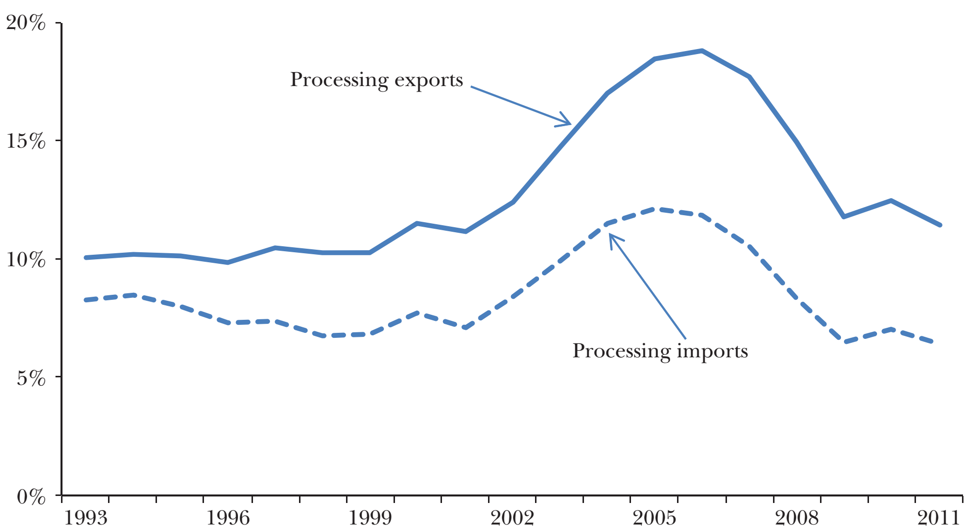
[7] Gravity equations are a common means of benchmarking trade flows. The volume of bilateral trade is related to the GDP/capita, population, and distance between trading partners.

Figure 3
Components of China's Merchandise Trade, 1993–2011
(percent of GDP)

A: Normal Exports and Imports



B: Processing Exports and Imports



Source: China Customs.

but it is important that the US share of the Chinese import market declined from 11.4 percent in 2001 to 7.7 percent in 2011 (calculated from IMF, *Direction of Trade Statistics*).

Even though Edwards and Lawrence (2013) argue that trade does not explain the post-2000 drop in manufacturing employment, they do show that the trade deficit does have a large jobs component, and its elimination would raise manufacturing employment by about 25 percent. During the boom years, Americans were relatively indifferent to the consequences of large trade deficits, but in the future, the United States cannot afford ongoing trade deficits of 3 percent and more of its GDP. Because of the domination of manufacturing in tradables, much of any adjustment will have to be concentrated in that sector. We now turn to a discussion of the future of US manufacturing and policies that would assist in reducing manufacturing trade deficits.

The Future of Manufacturing

Historically, the share of manufacturing employment in the total has declined by about 0.3 percentage points a year. The Congressional Budget Office projects civilian employment to be 159 million in 2023, so if the historical trend were to continue into the future, the implied level of manufacturing employment would be about 10 million, or about 2 million jobs below its current level. Although keeping this historical trend in mind offers a useful perspective, it is of course not set in stone, and there are more optimistic projections. One view is that market forces and new technologies are already aligned to bring about a re-shoring revolution, bringing jobs and production back to the United States. A somewhat different view is that the right set of government policies could generate a different future path.

In this section we look first at the importance of manufacturing to the economy. Is it special and does that mean special policies are needed? We look at how new technologies may impact manufacturing, and then at what policy changes might both help manufacturing and be justifiable economically.

Why is Manufacturing Important?

Any large sector of the economy deserves study, but manufacturing also has characteristics that make it of special interest. First, Americans live and work in a global economy in which they exchange products that they produce for those that they consume (and they wish to do so without a continuous decline in their terms of trade). Manufactures account for a very large proportion of tradables, and a large proportion of the industries in which the United States could potentially run a trade surplus. While the US economy does have a trade surplus in many services industries, it is not nearly substantial enough to offset continued large deficits in goods trade. Thus, in the context of the global economy, the United States must become a better exporter, and realistically that means more exports of manufactured products.

Second, a strong domestic manufacturing sector offers a degree of protection from international economic and political disruptions. This is most obvious in the provision of national security, where the risk of a weak manufacturing capability is clear. Overreliance on imports and substantial manufacturing trade deficits increase Americans' vulnerability to everything from exchange rate fluctuations to trade embargoes to supply disruptions from natural disasters.

Third, manufacturing is often identified as an area in which much of the country's research and development takes place, but as illustrated by industries such as pharmaceuticals and consumer electronics, manufacturing has become increasingly separate from research and development. Also the manufacturing that remains has become increasingly capital-intensive and the US economy performs well in the production of machinery for manufacturing.

Fourth, the long-term decline in the manufacturing share of employment has meant fewer jobs available at good wages for workers who lack advanced education (for example Goldin and Katz 2008). The loss of nearly 6 million jobs since 2000 has been damaging to workers who have been laid off, communities that have lost a vital source of employment, and to young workers who might have found jobs in the sector (Autor, Dorn, and Hanson 2013).

We agree with those who think manufacturing is important, but we do not agree that this justifies special treatment for the sector, such as special tax rates or other subsidies. Such policies are hard to enforce and an invitation to arbitrageurs who seek ways to capture the gains from such subsidies with little or no actual change in real behavior. However, certain policy decisions have had a particularly large adverse impact on manufacturing because it is so exposed to global competition. We will discuss these below.

Emerging Technologies in Manufacturing

The future of American manufacturing will largely be determined by the extent to which it can take advantage of various new technologies that will influence the structure of manufacturing in future years (for example, Hart, Ezell, and Atkinson 2012; McKinsey Global Institute 2013). There is at least suggestive evidence that technological innovation is continuing at a rapid rate; for example, the rate of issuance of patents to US residents has increased substantially since the 1970s, based on data from the US Patent and Technology Office (although there are problems of comparability over time with changing standards of what can be patented and how quickly patents are processed). In this section, we describe some of the most important emerging technologies in manufacturing: industrial robots and automation; additive manufacturing; advanced design; direct interconnections over the Internet between sensor and machines; materials science and biotechnology; and energy production. While these technologies have the potential to increase US-based output in many sectors of manufacturing, the number of net new jobs that would be created remains an open question.

The last few years have seen rapid strides in the technology of *industrial robots and automation*, allowing robots to perform tasks that can today only be performed by humans. Many of these tasks require dexterity that robots are only now acquiring, while others require minor adjustments and variances, which are difficult to program a machine to respond to. While industrial robots have been used in several industries for heavy lifting, dangerous operations, and repetitive, precise movements—painting and welding in the auto industry, for example—they have been priced well out of range for more regular "human" tasks. That could change soon with the development of robots that have the capability to work safely alongside humans. For example, a robot priced at $20,000 can now sense a human in the path of its arms and stop movement. It can be "reprogrammed" for new tasks by a human operator who physically manipulates its arms to move, bend, lift, or drop in the desired way. These low-cost robots have the potential to increase precision and raise productivity by reducing the number of workers required. Of course, robotics is a two-edged sword for US manufacturing employment. These advances could reduce the number of jobs for a given level of output, but at the same time, the advantage in labor costs currently held by Asian assembly and manufacturing companies would be reduced or eliminated, allowing production to be re-shored to the United States.

Additive manufacturing refers to a range of technologies, including 3D printing, that build up objects from small particles. Thus far, 3D printing has been used primarily to create prototypes or objects that would be impossible to machine; but in the future, companies will sell designs on the web, instead of selling products directly. Customers will be able to print out the desired product for themselves, or companies will provide 3D printing services on a contract basis. As the technology improves further, some products will be customized to match the specific demands of the individual customers. Additive manufacturing can increase flexibility, cut development costs and time, reduce material waste, eliminate tooling costs, and simplify production runs. How fast this technology will be deployed is hard to predict. But even now, when additive manufacturing is still expensive, it is becoming a standard tool for rapid prototyping and early production runs for small and complex components.

Increases in computer power and advances in software are leading to *advanced design*: that is, enhancing companies' ability to develop digital prototypes and carry out much more testing on the digital model before building a physical prototype. McKinsey Global Institute (2013) estimates there will be a 20–50 percent reduction in research and development costs as well as reduction in time to market.

The "Internet of Things" refers to how low-cost sensors will lead to a widespread array of *direct interconnections over the Internet among machines and locations.* Connecting machines will allow improved monitoring of production processes remotely and allow operators to provide instructions to one set of equipment based on activity at other equipment. Process designers will be able to set up systems that automatically make adjustments based on sensor readings from all the equipment in a network—and then apply optimization algorithms to improve efficiency. One specific example is to reduce energy usage. Traditionally, motors operate at peak capacity irrespective of load. However, smart motors are able to adjust power usage as output changes, usually through variable speed drives controlled by an intelligent motor controller. With low-cost sensors allowing improved inter-machine and system communication over wireless networks, it will be possible to make manufacturing systems that include thousands of smart motors, enabling substantial improvements in energy efficiencies in manufacturing. Connecting machines within a given factory, or even across multiple factories, will allow particular machines or conveyor belts to be shut down when not in use, saving energy and wear.

There have been breakthroughs in *materials science and biotechnology* that promise major advances ahead, although the timetable for adoption is unclear. Applying the technology to carbon nanotubes and graphene has allowed the creation of high-performance transistors and ultra-strong and light composite materials. Fluorescent nano-particles are used in biological labeling and solar cells. In biotechnology, nanoenabled technologies allow more rapid diagnosis of illnesses, detect contaminants, and provide glucose monitoring and many other applications. Bringing these advances into the economic mainstream will require long time horizons and continued investment.

Finally, although the recent developments in energy production technology are not manufacturing innovations, the extraction of natural gas and light tight oil from shale deposits will have a substantial effect on manufacturing. US natural gas resources have nearly doubled since 2003, driven by the development of shale deposits nationwide. The United States has the second-largest recoverable shale gas reserves in the world at 24 trillion cubic meters (after China's estimated reserves of 36 trillion cubic meters). However, the United States is substantially ahead of the rest of the world in having started to tap these reserves at increasing scale. By 2020, shale gas is expected to grow to over 25 percent of total natural gas production, which will lead to a 60 percent drop in natural gas imports. On net, US energy imports could fall to zero. Production of "light tight oil" (LTO), which also comes from fracking, has also developed rapidly. Current LTO production estimates for 2020 are between 5 and 10 million incremental barrels per day. US consumption of oil reached around 20 million barrels per day before the recession and has been around 19 million barrels per day since then (based on data from the Energy Information Administration). This new wave of energy production does raise legitimate environmental concerns, but it should be possible to develop the oil and gas fields responsibly.

Because natural gas is expensive to ship around the world and exports are restricted by regulation, the expansion of the North American supply will drive US prices for natural gas below world levels: for example, natural gas may very possibly be priced at $4–6 per million BTUs in the United States, well below the $12 price range in Europe and $16 in Asia. (Oil prices are set globally, but it is likely that US domestic prices will carry some differential below imported oil and that the greater security of domestic supply will be an attraction for users. West Texas Intermediate crude has been priced $10 to $15 a barrel below the Brent crude benchmark of international crude oil prices for much of 2013.) Cheaper natural gas will also keep electricity prices down. The cost of new capacity using natural gas turbines is estimated to be about 4 cents per kilowatt/hour at today's prices, compared to 6 cents for new coal-fired capacity and over 10 cents for nuclear or solar power.

Manufacturing tends to be an energy-intensive sector, and thus it benefits from the prospect of less-expensive energy supplies. Indeed, both US-based and global companies are already investing in new plants in the United States to take advantage of the lower price of energy and natural gas as a feedstock. PricewaterhouseCoopers (2012) suggested that the movement of energy-intensive sectors such as chemicals and plastics back to the United States would result in about one million new jobs in manufacturing, although this figure may be overoptimistic. After all, the most energy-intensive industries tend also to be the most capital intensive and have relatively low levels of employment. Additional manufacturing employment will come from the development of the new energy sources. McKinsey Global Institute (2013) estimates that exploiting the domestic oil and gas will require capital investment of $1 trillion over the next five to ten years. Another upside for the manufacturing sector from low energy prices is the potential for the US economy to shift part of its transportation system to natural gas, which would generate substantial demand for manufactured products. Some companies such as GM, Navistar, and Cummins are developing natural gas–powered trucks (Smith 2012), and in turn, some companies are already shifting their short-haul trucks to natural gas because of low fuel cost, a trend that could extend to long-haul trucks also if the refueling infrastructure is developed.

The main potential downside to US-based manufacturing from the increase in domestic energy production lies in a version of the "Dutch disease," which in this case refers to the way in which reducing net energy imports might raise the exchange rate and make domestic manufacturing less competitive.

What Role for Public Policy and Manufacturing?

Given the importance of the manufacturing sector, what policies will give growth and employment in this sector the best chance in the future? While we do not support special subsidies, it is important to ensure that existing policies are supportive of manufacturing—or at least do not discriminate against it. Our policy recommendations are all intended to make the United States a more attractive location for manufacturing production.

The macroeconomic factors creating the US trade deficit put US manufacturing at a disadvantage by distorting capital flows and the foreign exchange value of the dollar. The US economy has experienced an unusual confluence of factors that encouraged Americans to consume beyond their means financed by the steady sale of assets to foreigners in return for a large net inflow of imports. Going forward, consumption expenditures and investments in residential housing will constitute a smaller share of GDP. As of 2013, the US economy is making little progress in filling an ongoing production gap of about 5 percent of potential GDP. Yet consumption remains at an elevated share of GDP, financed by large but ultimately unsustainable fiscal transfers. Historically, the external trade deficits have been sustained by a shortfall of domestic saving compared to domestic investment, and it seems clear that insufficient levels of national saving drove up the exchange rate and priced US exporters out of foreign markets. The government has few if any tools by which it can dramatically raise private saving; thus, the increment to national saving will be achieved most effectively by steps to reduce the federal budget deficit.

This policy recommendation, which we have made forcefully in the past, is problematic at present because of the weakness of aggregate demand both in the US economy and around the world. The first priority of macroeconomic policy is to help restore full employment, and that goal would also help manufacturing. Fiscal consolidation in the very near-term could abort the recovery. Over the longer term, however, it is hard to see how the United States can significantly improve its trade balance without tackling the budget deficit.

We noted earlier that the US trade deficit is driven by low exports as much or more than high imports. We believe that US exports could benefit from trade negotiations that help to pry open foreign markets, and by negotiations with countries that manage their exchange rates about the appropriate level of their exchange rates.

Another important step that the US could undertake to become a more attractive location for manufacturing in a world of global supply chains involves its tax code. The marginal rate of corporate taxation in the United States is too high, particularly in relationship to the tax rates of other countries. In a world economy where choices about capital, technology, and production facilities are increasingly flexible, this is inducing firms to locate overseas. The United States has the highest corporate tax rate within the OECD, and, at a combined 39 percent, it exceeds the average by 14 percentage points. The United States needs to follow the lead of other countries in shifting toward greater reliance on consumption-based taxation.[8]

Both American companies and foreign companies investing in the United States report that the skills of the US workforce are comparatively weak. It lags behind many other countries in developing effective vocational education and job-training programs, and the educational attainment of young workers is falling behind that of countries like Canada, Japan, and Korea. Furthermore, US 15-year-olds rank 25th in math and 17th in science in PISA (Program for International Student Assessment) scores among OECD nations. Germany is an example of a country that has used a high-quality vocation education system to improve the skills of its workforce. Greater attention needs to be paid to reversing the deterioration in US workforce skills.

Similarly, the United States suffers from a deteriorating physical infrastructure that raises the costs of production and limits the location of export activities. The extraordinarily low level of current interest rates suggests that now is an ideal time to engage in long-term borrowing of funds to finance the repair and modernization of those systems. Such financing, if matched by a credible dedicated revenue source

[8] The United States also attempts to tax the foreign income of US companies, albeit with a deferral. Most other countries use a territorial-based system in which income is taxed only in the country in which it is earned.

for repaying this debt, would not add to concerns about an unmanageable level of general fund debt.

Supporters of manufacturing often stress the need for government support of technology (Atkinson, Stewart, Andes, and Ezell 2012). We agree, but as described earlier, US companies remain strong in technology development while viewing it more profitable to produce the technology goods overseas.

Manufacturing is an important sector and needs to be competitive in order for the US economy to return to full employment with a sustainable trade balance. But improving the US export position cannot be quickly achieved. It will take years to rebuild the domestic supply chain and undo the incentives that have encouraged American firms to shift their production abroad. The key to expanding US exports and reaching manufacturing's employment potential is to have companies, domestic and foreign, judge it is profitable to manufacture here.

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