Why Manufacturing Matters

The evidence is substantial that U.S. performance in manufacturing has weakened, that several important American industries do not measure up to the competition, and that the trouble cannot all be laid at the door of the high dollar. The next question to ask is whether it matters. Does the Nation really need a strong manufacturing sector? Or has the time come to gradually cede production of goods to other countries while in this country manufacturing gives way, in a natural and desirable progression, to performance of services?

The answer, for now and the foreseeable future, is that there is no choice to made between manufacturing and services. The nation needs both. As we have seen, manufactured goods are indispensable for trade with other nations. It is also clear that America has not entered a post-industrial stage; the demand for manufactured goods by consumers, businesses, and government is greater than ever. Moreover, to speak of services as taking the place of manufacturing in the economy is to overlook the strong interdependence of the two kinds of activities and the blurring of distinctions between them. Many manufacturing industries could hardly exist without allied services; the manufacture of computers and design of software (often by an independent firm) are an obvious example. It works the other way as well. For instance, manufactured hardware makes it possible for hospitals to offer highly sophisticated radiology services such as magnetic resonance imaging and computerized tomography.

There are worrisome aspects to this interdependence. With the great rise in imports of manufactured goods in the 1980s, a large number of jobs were lost in manufacturing, and with them went some closely associated jobs in the service sector. OTA's analysis suggests that about 6.5 million service sector jobs were tightly linked to manufacturing in 1984. Altogether, some 27.7 million U.S. jobs were involved in manufacturing, either directly or indirectly (i.e., producing services or material inputs for manufacturing). Jobs associated with manufacturing are generally good ones. Manufacturing wages, overall, are higher than wages in the service sector. Most of the jobs in producer services that are closely tied in with manufacturing are also better than average. To keep these good jobs, as well as good jobs in the manufacturing sector itself, America must compete effectively in the production of goods.

Links Between Manufacturing and Services

It is hardly novel to observe that manufacturing and services are interdependent. When Adam Smith remarked in 1776 that "the labour . . . of artifices, manufacturers and merchants naturally does fix and realise itself in some such vendible commodity" he was noting that merchants, although in a service occupation, are among the workers involved in bringing goods to the final purchaser.[83] There are many other sorts of connections as well. Before reaching the merchant who sells it, the vendible com-

[83] Adam Smith, The Wealth of Nations, Book IV, chapter IX, cited in J.I. Gershuny and I.D. Miles, The New Services Economy: The Transformation of Employment in Industrial Societies (New York, NY: Praeger, 1983).

modity must first pass through the hands of truckers and warehousers who provide transportation and storage services. Farther upstream, bankers and venture capitalists, insurance companies, lawyers, engineering consultants, temporary help agencies, and computer specialists all contribute to the production of commodities. The service industries, in turn, are important customers of the manufacturing sector. For example, according to one study, 80 percent of the computing, communications, and related information processing equipment sold in the United States in 1982 was purchased by the service sector.[84]

Specialized technical skills are particularly in demand for the manufacture of innovative, high technology products. In microelectronics the links between manufacturing and services are exceptionally close. The highly successful U.S. computer manufacture industry could not have developed without constant interaction between hardware engineers and software designers. Software itself is an excellent example of the marriage of manufacture and services, since it has the character of both a good (it can be stored and shipped) and a service (computer programs are not immutably fixed).

Some kind of services, however, are not very closely tied to the location of goods production. In general, the service activities downstream of manufacturing–trucking, warehousing, and wholesale and retail sales of the final product –are not tightly linked with domestic manufacture.[85] Most of these services can just as well take place with goods shipped halfway across the world.[86] On the other hand, upstream services —those that manufacturing firms use as inputs in producing goods —tend to be linked much more closely to the place where the goods are made. These upstream services include such things as process engineering, machinery repair, trucking of goods between related industries, janitorial services, testing and lab work, payroll and accounting services. So long as manufacturing stays home, so will these services and the jobs and national income they generate. If domestic goods are displaced by imported ones, or if U.S.-owned manufacturing operations are moved offshore, then many of the tightly linked upstream services will go with them.

Not all upstream services are so tightly bound. An obvious case is advertising; American agencies, for example, create television ads for Japanese cars. Thanks to telecommunication, some software design has now migrated overseas, e.g., to India, where salaries for engineers are much lower than for their American counterparts. And it is quite possible for foreign banks to lend money to U.S. manufacturing enterprises. By and large, however, upstream services that are inputs to manufacturing stay or go with the manufacturing activity itself, for the simple reason that most services are not very transportable, and are produced near the place where they are consumed.

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84 Cited in: James Brian Quinn and Christopher E. Gagnon, "Will services follow manufacturing into decline, ''Harvard Business Review, November-December 1986, p.96).

85 For a detailed discussion of linkages, not only of services and manufacturing, but also of the production of various kinds of goods with each other, see Stephen S. Cohen and John Zysman, Manufacturing Matters: The Myth of the Post-Industrial Economy (New York, NY: Basic Books, Inc., 1987), ch. 2.

86 It should be noted that foreign manufacturers selling in the United States do often set up their own wholesale distribution centers; an example is Japanese multinational investment in the United States, which is heavily weighted to wholesale establishments. Many of the jobs, and a good deal of the income, generated by these establishments go to Americans.

So long as the upstream services are provided by employees of manufacturing firms, they are apportioned in the national accounts to manufacturing output and employment. Often, however, they are provided by outside firms, in which case the national accounts attribute to the service sector activities that are really a part of the fabric of manufacturing. Among the fastest growing sectors in the U.S. economy are those that provide services to companies, rather than consumers. While total employment in all the private service sectors grew at an average rate of 2.6 percent between 1973 and 1986, the number of jobs in business services — which includes advertising, computer software and data processing, temporary help agencies, management services, and research and development laboratories — grew by 7.5 percent a year. Likewise, miscellaneous professional services (including architectural and engineering services and accounting, auditing and bookkeeping) increased at the rate of 5.2 percent per year.

Some of this great expansion in business and professional services in recent years was tied to manufacturing. To get a quantitative idea of the connections between manufacturing and services, an input-output model is helpful. The model can provide estimates of how much the manufacturing sector buys from service industries in the process of making goods and how many jobs are involved, and vice versa. In 1984, private service industries supplied 17 cents of inputs toward each dollar of manufacturing output. Manufacturing in turn contributed 12 cents worth of inputs toward each dollar of output of the private service industries.[87]

The same kind of exchange held for employment. Many of the jobs counted in the service sector are really closely involved in manufacturing. Estimates based on OTA's input-output model indicate the jobs involved in producing services that are inputs to manufacturing numbered about 6.5 million in 1984.[88] In addition, 1.8 million jobs in agriculture, mining, and construction were linked to manufacturing in the same way (table 8). There were 19.4 manufacturing jobs in 1984. Add to that the 6.5 million jobs in service industries and 1.8 million in natural resources producing inputs for manufacturing, for a total of 27.7 million jobs involved, directly or indirectly, in manufacturing. In turn, some 6.5 million manufacturing jobs were devoted to making inputs for the service and natural resource sectors, Workers in these jobs produce goods ranging from tractors to sewer pipes to computers to CAT scanners to paper clips, needed for the conduct of business by enterprises as diverse as farms, sanitary services, banks, hospitals, and insurance offices.[89]

At a finer level, the service industries that are most closely involved with manufacturing are wholesale trade, transportation and warehousing, business services, gas, electric and sanitary utilities, and radio and

87 This exchange is on the basis of gross output of the manufacturing and private service sectors. The figures do not include purchases of capital equipment or structures needed to produce industry output.

88 The OTA model was developed for the assessment Technology and the American Economic Transition (op. cit.). OTA's model is based on the 1980 input-output tables and is updated to 1984 for employment and sectoral demand. It includes capital flows.

89 Estmates of services jobs closely linked to manufacturing, manufacturing jobs to services, and links of both these sectors with natural resources are adapted from the OTA model.

television broadcasting. Each contributes more than 20 percent of its employment to meeting manufacturing demand (table 8). In numbers of jobs, wholesale trade and business services are most prominent, together accounting for about 2.6 million of the 6.5 million jobs involved in service sector inputs to manufacturing in 1984.[90]

The picture emerging from this analysis is interdependence — not primacy of manufacturing as a solid base on which a rather flimsy superstructure of services is erected, nor on the other hand a succession in which services are ousting manufacturing from a place of economic importance. One can also conclude that if manufacturing production and employment is lost, services cannot

Table 8.–Workforce Involved In Manufacturing and Average Full-Time Equivalent Compensation, 1984

	Wage and salary workers involved in manufacturing	Percent of sector employment involved in manufacturing	Average annual full-time equivalent compensation (thousands of dollars)
Agriculture	792	50,4%	$11,3
Mining	443	45.5	37,0
Construction	575	13.3	26,8
Manufacturing	19,396	1000	287
All public and private services	6,492	9.4	246
All private services	6,343	11.9	244
Wholesale trade	1,501	26.3	27,6
Transportation and warehousing	704	242	303
Business services	1,276	22.8	24,7
Radio and IV broadcasting	50	218	29,6
Electric, gas, water and sanitary services	171	214	37.5
Communications, except radio and television	129	116	397
Automobile repair and services	79	116	178
Retail, except eating and drinking	1,176	103	171
Finance and insurance	413	90	27.4
Hotels, personal and repair services (exe. auto)	207	85	157
Eating and drinking places	428	79	110
Real estate and rental*	72	67	211
Amusements	46	4.5	19.9
Health, educ. & social serv. and nonprofit org.	89	0.9	20.2
Government	149	0.9	31,1
Total	27,697	29.0%	$274

SOURCE. 'Workers involved in manufacturing data derived from OTA Input-Output Model (1980 technical coefficients, 1984 estimated demand, 1984 BLS employment, adjusted for capital flows, imports and duties) Compensation data dewed from Bureau of Economic Analysis, National Income and Product Accounts, electronic data, mapped to Input-output industry classifications

90 The 1980 input-output tables, on which OTA's model is based, cover only 85 industries, with wholesale and retail trade lumped together. A much finer mesh, covering 537 industries and posting wholesale and retail trade separately, was published for 1977, the benchmark year. For this report, OTA used the 19?7 input-output tables to separate wholesale from retail trade, and thus to derive estimates of employment associated with manufacturing for each separately.

simply and directly replace them. A substantial number of service jobs depend directly on the presence of manufacturing. Manufacturing and services are strongly enough linked that they will prosper together or decline together.

Links between suppliers and customers may also be quite close among different manufacturing industries. Of course this is not always the case, since goods can be stored and shipped much more readily than services. For example, U.S. automakers buy components and parts, from engines to windshield wipers, all over the world. At the same time, some major automakers, and other manufacturers as well, are developing stronger bonds with local suppliers. Having suppliers close by enables companies to use just-in-time deliveries, and helps in developing long-term, cooperative relations with the suppliers–both key elements in Japanese manufacturing strategy. In the textile/apparel business, for example, a leading U.S. maker of jeans has completely changed its relations with denim suppliers in the past few years. Instead of driving the hardest possible bargain on price with competing suppliers, the company now buys most of its denim in long-term arrangements from two or three textile manufacturers, gaining the advantages of consistent high quality and just-in-time delivery. In fact, the jeans manufacturer now keeps virtually no inventory and has turned an entire warehouse into sewing space.

Different segments of whole industry complexes may depend on each other to a greater degree than one might suppose, if relations between supplier and manufacturing purchaser were governed only by technical possibilities and not at all by spatial bonds. Cohen and Zysman draw examples from agriculture; they say:[92]

> It is technically possible, but economically improbable to mill sugar cane in a country far from the sugar fields, or to process tomatoes far from the tomato patch, or to dry grapes into raisins or crush them for wine far from the vineyard. It is a forward linkage starting with farming; food processing is downstream in the production chain . . . In agriculture, both in theory and in what is too often dismissed as mere real-world examples, tight linkages bind in both directions. There are many activities tightly bound to farming that are backward linkages: crop dusters, animal vets, harvesters, tractor repairers, mortgage appraisers, fertilizer salesmen, blight insurers, agronomists, chemists, truckers, shuckers.

The fiber/textile/apparel complex provides another example. It is conceivable that American textiles could be sold to Hong Kong apparel makers, but the U.S. chemical companies that make fibers and the textile companies that spin and weave the fibers are not counting on it. Both are taking a leading role in strategies to strengthen the U.S. apparel industry, partly by forging stronger links among all segments of the industry, from textiles to apparel to designers and retailers. (Some of the chemical companies

91 OTA interview with Thomas O'Gorman, President, Greenwood Mills,
92 Cohen and Zysman, op. cit.

are also hedging their bets by producing fiber in Southeast Asia, near textile and apparel manufacturing centers.)

An input-output model is not much help in showing the strength of the ties between manufacturing companies. It can show what materials or intermediate goods one industry buys from another, but not whether one depends on the presence of another in the same national economy. For an accurate view of the strength of these spatial bonds, empirical studies of individual manufacturing industries are needed; OTA's full assessment of Technology, Innovation, and U.S. Trade will discuss these kinds of connections in several manufacturing complexes.

Manufacturing and the Quality of Jobs

The kinds of jobs associated with manufacturing are important as well as the number. Pay is better in manufacturing than in the private services overall, and has consistently been so for many years. Moreover, the services jobs most closely connected with manufacturing tend to pay better than services in general.

Total compensation –wages, salaries and benefits –of people employed in manufacturing in 1984 was $28,700; for all workers in the services, it was $22,900, and in the economy overall, $24,300 (see table 8).[93] Jobs in transportation and warehousing, radio and TV broadcasting, and utilities paid as much or more than the manufacturing sector itself, and they are closely linked to it. Over 20 percent of their output goes into manufacturing as inputs, compared to less than 12 percent in private services as a whole. Business, legal, and professional services, a category that includes everything from janitors to corporate tax lawyers, is also closely tied to manufacturing; jobs in this group of industries paid above average for the services, but below manufacturing. Wholesale trade, which has a higher proportion and larger number of jobs (1.4 million) associated with manufacturing than any other service industry, paid nearly as well as manufacturing.

Some service industry groups that do not sell a large share of their output to manufacturing still devote a large number of jobs to manufacturing input. The most important of these is retail trade, which had 1 million jobs associated with manufacturing in 1984, and retail pay is low; Yearly compensation (per full-time worker) averages $17,100. Others with fairly large numbers of jobs linked to manufacturing but low pay are eating and drinking places ($11,000) and hotels and personal services ($15,700). These three low-paying industry groups employed one-quarter of the U.S. service sector workers making inputs for manufacturing in 1984. OTA has calculated the average compensation for jobs in all the service sectors tightly linked to manufacturing at $24,600, compared to $22,900 in the services as a whole, in 1984.[94] The difference in pay between private (non-government) services linked to

93 All compensation figures are given on a full-time worker basis; this eliminates a downward bias in compensation for the service industries, which have a greater share of part-time jobs than manufacturing. Numbers of workers are also given as full-time equivalents. The reason for choosing 1984 as the year for comparing compensation in different sectors is that OTA's input-output analysis showing relations between service and manufacturing jobs was done for that year. Pay in manufacturing jobs and in service jobs associated with manufacturing remained better than in service jobs generally in 1986.

94 This is a weighted average, based on the data in table 8.

manufacturing and all private service industries is even more pronounced – $24,400 versus $21,900.

What is the basis for the longstanding superiority of wages in manufacturing, and in services closely related to manufacturing, over the rest of the economy? Possibly, higher output per employee hour. It has long been considered a truism that productivity is better in manufacturing than in services. This is not entirely true. What does seem to be true is that manufacturing *and* the distribution and producer services with closer than average links to manufacturing have higher than average productivity as well as higher than average pay. The obverse does not hold, however. Finance, insurance, and communications have high productivity and pay well, even though they have only an average, or below average, degree of association with manufactur ing.

According to official figures compiled by the Bureau of Labor Statistics (BLS), productivity growth in manufacturing has been higher than in private business as a whole for many years, since 1960 at least (table 9). The discrepancy appears especially remarkable in recent years. From 1979 to 1987, manufacturing productivity rose at an annual rate of 3.4 percent, while for private business as a whole *(including* manufacturing), the yearly growth rate was 1.3 percent. Leaving out agriculture, the growth rate for all private business was only 1.1 percent. These figures seem to mean that manufacturing has carried the whole economy on its back in raising productivity, especially since the 1970s. Recall, however, that the produc-

Table 9. – Productivity in Manufacturing and All Business, 1980-87
(1977 = 100)

Year	All business	Manufacturing
1960	67.3	62.2
1961	69.7	64.0
1962	72.3	66.7
1963	75.2	71.2
1964	78.4	74.6
1965	80.8	76.6
1966	82.9	774
1967	85.2	77.4
1968	87.6	79.8
1969	87.7	80.8
1970	88.4	808
1971	91.3	85.3
1972	94.0	89.0
1973	95.9	934
1974	93.8	906
1975	95.7	929
1976	98.4	971
1977	100.0	100.0
1978	100.8	**1015**
1979	99.5	**1014**
1980	99.2	**1014**
1981	100.6	**1036**
1982	100.3	**1059**
1983	103.0	**1120**
1984	**105.6**	**1181**
1985	**107.5**	**1242**
1986	**109.5**	**1288**
1987	**110.5**	**1330**
Annual average growth rates		
1960 73	**28**	32
1973 79	**06**	14
1979 87	**13**	34

SOURCE. U S Department of Labor, Bureau of Labor Statistics, electronic data, Monthly Labor Review, various Issues, table 44

tivity figures are based on a constant-dollar series for gross national product that may substantially understate the share of manufacturing in GNP for earlier years — and thus overstate its growth in real output, value added, and productivity.[95]

Another way to compare productivity of manufacturing and various service industries is to look at their respective levels (not growth rates) in one recent year, thus avoiding the problems of using a constant dollar series over time. For this purpose, productivity can be calculated as value added in an industry or sector, divided by the number of hours worked in that industry.[96] On this basis, manufacturing productivity in 1986 was $20.27 an hour, compared to $18.08 for all private services averaged together (see table 10).[97] The average conceals a more interesting story. Business and professional services and the transportation and warehousing industry, all of which devote over 20 percent of their output to manufacturing, are virtually the same as manufacturing in productivity. Public utilities, another industry with close links to manufacturing, has exceptionally high productivity–over $65 of value added per hour. Wholesale trade, with its high proportion and large number of jobs involved with manufacturing, has productivity well above average.

Table 10.-Value-Added per Hour, by Industry, 1986

	Value added hour	Percent of sector employment involved in manufacturing
Agriculture	$12.68	50.4%
Mining	54.55	45.5
Construction	1563	13.3
Manufacturing	20.27	100.0
Public and private services	20.21	9.4
All private services	21.86	11,9
Wholesale trade	24.31	26.3
Transportation and warehousing	21,25	24.2
Business services	19,60	22.8
Radio and TV broadcasting	27.49	21,8
Electric, gas, water and sanitary services	65.31	21.4
Communications, except radio and television	45,93	11,6
Automobile repair and services	15.16	11,6
Retail, except eating and drinking	12.62	10.3
Finance and insurance	20.58	9.0
Hotels, personal and repair services (exe. auto)	10.63	8.5
Eating and drinking places	1541	7.9
Real estate and rental*	161.28	67
Amusements	14,51	45
Health, educ. & social serv. and nonprofit org.	1323	0.9
Government.	14.57	0.9
Private services excluding real estate	18.08	12.0
Total	$1777	22.1%

Value-added includes inputed rent from other sectors of the economy

SOURCE: Value-added by industry from U S Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts, Gross Product Originating by Sector, electronic data, hours of all persons engaged from U S Department of Labor, Bureau of Labor Statistics, Office of Economic Growth, Hours of All Persons, unpublished data, workers involved in manufacturing dewed from OTA Input-Output Model (1980 technical coefficients, 1984 dewed demand, 1984 BLS employment, adjusted for capital flows, imports and duties)

95 If the constant-dollar value added figures are taken literally, the level of productivity in manufacturing was much lower than in services, and in the economy as a whole, until quite recently. For example, using the BEA series on value added in 1982 dollars, manufacturing output per full-time equivalent employee in manufacturing appears to have been $20,900 in 1960, compared to $2S,700 for private services (excluding real estate), and $29,200 for the economy as a whole; for 1986 the comparable figures are S44,000 for manufacturing, $32,800 for private services except real estate, and $38,700 for the whole economy. A series calculated on the basis of constant 1982 dollars shows the level of productivity in manufacturing lower than that of the economy as a whole from 1960 through 1982. In fact, since the figures are still relatively close together, the only way productivity could have grown so much faster in manufacturing than in the rest of the economy for such a long time is to have started at a much lower level.

96 Value added is the difference between the cost of materials, parts, and services that an industry buys to produce an item or service, and the sales revenues the industry collects. The constituents of value added, as usually calculated, are wages, interest, rent, profit, depreciation, and indirect taxes.

97 As noted in table 8, real estate is excluded from this calculation, because in the national income and product accounts, real estate value added includes not only agency fees but also all rents and all imputed rents for owner-occupied dwellings. By this definition, value added in real estate is not really equivalent to value added in other sectors, but is more like gross output, and is inconsistently high.

Highly productive enterprises and good jobs certainly exist in service industries other than those closely linked to manufacturing. The communications industry, including telephone and telecommunication services but excluding radio and TV broadcasting, is near the top in productivity, but has no more than average links with manufacturing. Finance and insurance, a very large sector with employment of 4.9 million in 1986, has productivity equal to that of manufacturing, but is not at all strongly linked. It is also true that none of the service industry groups at the bottom of the heap in productivity – consumer, social, and retail services — is very closely tied to manufacturing (11 percent or less of their output goes into manufacturing).[98] Value added per hour in these industry groups is down in the range of $12 to $13.

All this said, it must be recognized that there is something quite unsatisfactory about comparing productivity from one sector to another. Ideally, productivity would be calculated on the basis of how many man-hours it takes to produce a physical quantity of a good or standard unit of service. The BLS does produce productivity studies of this sort for specific industries. But goods are unlike each other, and services are more different still. To look at productivity in the economy as a whole, or across sectors, the only common unit of measurement is dollars.

It may seem straightforward enough to figure productivity in both goods and services as value added per hour. But what is value added? By definition, it is the sum of wages, interest, rent, profit, depreciation, and indirect business taxes in the sector or industry under consideration. A large proportion of value added, varying by industry but generally about one-half to two-thirds, is wages and salaries plus corporate profits. Thus, if wages and profits are relatively high in an industry, its value added, and therefore its productivity, will show up as high. This may reflect genuinely high productivity-that is, high physical output per hour worked; indeed, the economic foundation for good wages and living standards is high productivity. But within an economy, one sector's wages may be higher than another for reasons other than productivity.

An industry with a lot of market power, i.e., in a near-monopolistic position, can often extract higher prices, and therefore pay higher wages and profits, than one that is more competitive but equally efficient in using labor. Consider steel up until the late 1970s, before international competition and declining demand destroyed the industry's market power. The steel industry paid premium wages, and on the basis of value added, had above average productivity growth in the 1970s. But on the basis of physical output per hour (as calculated by the Bureau of Labor Statistics), steel's productivity growth was below the all manufacturing average for most of the decade.[100] By contrast, agriculture, which has shown strong productivity growth in physical measure-

98 Note, however, that a very large number of retail trade jobs is associated with manufacturing, even though the proportion of linked jobs in this very large sector is only 11 percent.

99 Other factors also affect the ability of near-monopolistic industries to set prices above a competitive level, and thus pay higher wages and profits than they otherwise could. These factors include the degree of elasticity of demand for labor, the elasticity of substitution between labor and capital, and the elasticity of demand for the Industries' output,

100 U.S. Congress, Office of Technology Assessment, U.S. Industrial Competitiveness: A Comparison of Steel, Electronics, and Automobiles (Washington, DC: U.S. Government Printing Office, 1981), pp. 56-67.

ments of output (such as bushels of wheat per hour worked), is highly competitive, pays low wages, and has low value added in dollar terms. Also, strong unions can raise wages; and social practices such as paying nurses (female) less than truck drivers (male) can lower pay. Because of these other influences on wages and profits, value added (divided by employee hours) is no more than a rough guide to levels of productivity indifferent industries.

The fact remains that manufacturing pays better than services, and so do linked services. This at least suggests that manufacturing is able to pay both its employees and its service suppliers relatively well because of superior productivity. This does not mean that other services cannot provide good jobs. Within the designation of "services'' are very different kinds of activities; all they have in common is that they do not produce tangible goods, and even that distinction is blurred in some industries, such as software. Some industries in this disparate collection do indeed have low productivity and pay, and employment in these industries (e.g., retail trade) is so large that they pull down the average pay for services in general. Of the service industries that are better paid and more highly productive, several have in common a substantial dependence on advanced technology (e.g., computers in banking, insurance, and telephone communications), or high capital investment per worker (e.g., public utilities), or both.[101] These features are also found in the services most closely linked to manufacturing.

High Technology Industries

Manufacturing industries at the cutting edge of technology, in products or processes, help to buoy the economy, provide new jobs, improve the trade balance, and advance technology outside their own industry as well as within it. Traditionally, whatever industries were at the technological forefront for their time have helped to give the United States a competitive edge. The criteria widely used to define high technology industries are higher than average ratios of technology-oriented workers, and average or higher than average research and development spending.[102] A list of 26 manufacturing industries based on these two criteria includes most of the ones that people intuitively select as high tech (table 11). Among them are computers, electronic equipment and components, communication equipment, precision instruments, specialized engineering products, aerospace, chemicals, and drugs.

Clearly, high tech industries are vital to the nation's future. The development of knowledge-intensive, technologically advanced products and methods of manufacture, from supercomputers to robotics to biotechnology, is indispensable for a better quality of life and rising incomes. The question, however, is whether high tech industries can fill the gaps left by the decline of traditional manufacturing industries, creating high wage jobs and making goods for export to offset imports of standard products made by lower wage workers in

101 For an in-depth discussion of different kinds of service industries and a classification based on knowledge-intensiveness, see U.S. Congress, Office of Technology Assessment, International Competition in Services, OTA-ITE-328 (Washington, DC: U.S. Government Printing Office, Juty 1987).

102 This is the definition of Grou 111 high technology industries developed by the Bureau of Labor Statistics; see Richard W. Riche, Daniel E. Hecker, and John U. Burgan, "High Technology Today and Tomorrow. A Small Slice of the Employment Pie,'' Monthly Labor Review), November 1983.

Table 11. - U.S. High Technology Manufacturing Industries

Electrical components and accessories
Office computing and accounting machines
Communication equipment
Aircraft and parts
Measuring and controlling instruments
Surgical, medical, and dental instruments
Guided missiles and space vehicles
Drugs
Miscellaneous electrical machinery
Soaps, cleaners and toilet preparations
Industrial organic chemicals
Optical instruments and lenses
Engineering, laboratory, scientific and research instruments
Photographic equipment and supplies
Agricultural chemicals
Miscellaneous chemical products
Industrial inorganic chemicals
Engines and turbines
Petroleum refining
Electrical industrial apparatus
Ordnance and accessories
Paints and allied products
Special industry machinery
Electrical, transmission and distribution equipment
Radio and IV receiving equipment
Plastic materials and synthetics

NOTE. High technology manufacturing industries are defined as those with a proportion of technology -oriented workers (engineers, life and physical scientists, mathematical specialists, engineering and science technicians and computer specialists) equal to or greater than the average for all manufacturing industries, and a ratio of R&D expanditures to sales close to or above the average for all Industries

SOURCE Richard W Riche, et al , "High Technology Today and Tomorrow a Small Slice of the Employment Pie," Monthly Labor Review, November 1983

other countries, as some have suggested.[103] The answer is no. High tech industries do not stand alone, any more than services. Though they are necessary to the generation of jobs, wealth, and exports, they cannot do the job alone.

A great many of the products of high tech industries are intermediate goods used by other industries, both other high tech industries downstream (e.g., computers) and more traditional industries (e.g., autos). There is little consumer demand for semiconductor chips, lasers, or programmable machine tools. The big consumer demand is for goods such as cars, compact disk players, microwave ovens, and washing machines which, increasingly, contain advanced technology products or are made by advanced manufacturing methods. For example, the auto industry is one of the largest users of computer aided design and computer assisted manufacturing equipment (CAD-CAM), robots, and sophisticated machining centers, and is also one of the largest purchasers of semiconductor chips.

Semiconductors illustrate the point that high tech industries depend on other industries to buy their wares. Excluding captive producers (e.g., IBM and AT&T) who make chips mostly for their own use, 85 percent of the 1986 output of the U.S. industry went to non-military industrial customers, who use semiconductors in the process of manufacture or embed them in autos or other consumer goods. About 40 percent of the chipmakers' output went to manufacturers of data processing equipment (including computers), and another 15 percent to producers of communications equipment. Sixteen percent went to industrial machinery and equipment, 7 percent to consumer electronic goods and 8 percent to transportation equipment.[104] Strong demand from the semiconductor-using industries, both traditional and high tech, is fundamental to the strength of the semiconductor industry itself.

Of course, that demand need not all be domestic demand. The United States does

103 See, for example, Robert Z. Lawrence, Can America Compete? (Washington, DC: The Brookings Institution, 1984), ch. 4,

104 National Science Foundation, The Semiconductor Industry, report of a Federal Interagency Staff Working Group (Washington, DC: National Science Foundation, 1987), p. 6, chart 2, based on in format ion from Dataquest.

have a large share of the world market, but that share is declining, while the Japanese portion is rapidly increasing. Considering only sales of merchant producers, excluding captive consumption in both countries, U. S.-based companies had 40 percent of global semiconductor revenues in 1986 compared to 48 percent for the Japanese.[105] U.S. trade in semiconductors has been in deficit since 1982.

The Japanese semiconductor industry has benefited from strong demand from Japanese manufacturers of consumer products. According to one source, 40 percent of Japan's semiconductors went into consumer products in 1986; the industries included consumer electronics such as television sets, VCRs, compact disc players, and audio equipment. The consumer electronics industry has almost vanished from America (except for Japanese and Korean owned plants that assemble parts imported from the home country); consumer products took only 7 percent of the U.S. semiconductor industry's output in 1986.[106] The demand from consumer products in Japan is not only large; a goodly share of it is reliable, owing to vertical integration that fosters close links between production of semiconductors and end uses. This strong, steady demand provides the wherewithal to pay for successive generations of new equipment. It is one of the factors enabling the Japanese semiconductor industry to develop advanced manufacturing technology that improves yields and cuts manufacturing costs.[107]

Another kind of link is the pool of skills available from traditional manufacturing to further innovation in high tech manufacturing. Invention of new products is often not enough by itself to confer a competitive advantage; the inventor needs manufacturing know-how and other supporting technologies to capitalize on the invention. For example, underneath the creative ferment of new inventions in microelectronics in Silicon Valley is the presence of scores of metalworking job shops with skilled machinists on hand.

Limits on traditional manufacturing skills may limit the possibilities of high tech innovation. The VCR story supplies an example. One reason RCA chose to go with its ill-fated videodisc system (which was unable to record) instead of cassette tape, was that the complex and precise assembly required for the tape player proved to be extraordinarily difficult and expensive; the company thought manufacturing costs would put too high a price tag on the equipment.[109] Although it took years to accomplish, the Japanese producers did eventually achieve

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105 Ibid, p. 10. According to this source, shipments from U.S. based plants, including captives, were 52 percent of the world total in 1985, but had slipped from 61 percent in the 3 years since 1982.

106 Ibid., p. 6, chart 2.

107 Michael Borrus, James E. Millstein and John Zysman, "Trade and Development in the Semiconductor Industry: Japanese Challenge and American Response," in John Zysman and Laura Tyson, eds., American Industry in International Competition (Ithaca, NY: Cornell University Press, 1983).

108 David Teece, "Profiting from Technological Innovation, ''Research Poli, 1986, vol. 15, no. 6; Nathan Rosenberg, "Technological Interdependence in the American Economy,''Technology and Culture, January 1979, pp. 25-50.

109 The projected high cost and difficulties of making cassette tapes, plus severe standardization problems, were other hurdles, probably even more important than the cost of machining and assembling the player. However, the rising cost estimates for the player (up from $450 to $750 as of early 1971) and continuing difficulties in manufacture were central factors in RCA's decision to give up the videocassette recorder and go with the Videodisc. See Margaret B. W. Graham, RCA and the VideoDisc: The Business of Research (Cambridge, England and New York, NY: Cambridge University Press, 1986), especially pp. 128-1.38 and 148-150.

the necessary precision economically, both for VCRs and for miniaturized products such as Sony's Walkman.

None of this is to underrate the past contributions of high technology industries in America and the importance of their continued development. Several of these industries have expanded much more strongly than manufacturing in general in recent years, and have added jobs even as their productivity soared. For example, employment in computer and semiconductor manufacture combined grew from 520,000 in 1979 to 679,000 near the end of 1987.[110] In the 26 high tech manufacturing industries altogether, employment also rose, but more modestly, from 5.1 million to 5.3 million.

As discussed below, the surpluses of past years in hightech trade have nearly vanished. High technology industries face increasingly stiff competition, both from lower wage but rapidly industrializing Asian countries, and from the higher wage but highly competitive Japanese. World demand for goods related to microelectronics is expected to go on rising strongly, but American manufacturers will have to scramble to keep their share of demand and their output growing. One ingredient in success has to be reliable demand for high tech goods by a strong American manufacturing sector.

[110] The composition of employment changed in computer manufacture, however; while total employment rose from 320,000 to 406,000 from 1979 to 1987, jobs for blue-collar production workers dropped from 131,000 to 128,000.