Productivity in aircraft manufacturing

Owing in part to a strong performance in 1991, productivity rose an average of 3.2 percent during the 1972–91 period; however, the average rate of growth in the industry during the 1980's was substantially lower

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Lately, the news has not been good for aircraft manufacturers. Because of the financial turmoil in the airline industry, production rates for new civilian aircraft have fallen in the face of decreases in new orders and cancellations and postponements of orders already on the books. The military sector is heading toward a potentially historic downturn that may significantly depress demand in the long run. Plants are closing, some companies are leaving the aircraft business altogether, and others have gone bankrupt. Tens of thousands of employees have lost their jobs, and many thousands more are at risk.[1] Even in international trade, the usually good news is somewhat moderated. Published analyses have been pointing out that, while U.S. aircraft manufacturers maintain a very strong trade balance, the percent of the U.S. market share of free world production has slipped steadily since the mid-1980's, due to the entrance of Airbus and other foreign competitors into the market.[2] Now, a new BLS study shows that the industry's productivity performance has also been mixed.[3] As measured by output divided by employee hours, productivity increased 3.2 percent per year over the 19-year period from 1972 to 1991. The performance is clouded, however, by the fact that the long-term rate was made up of two very different periods, 1973–79, when productivity rose 3.8 percent annually, and 1979–90, when it rose, on average, just 0.3 percent annually. (These periods were selected because the years 1973, 1979, and 1990 were all peak years of business cycles, as determined by the National Bureau of Economic Research.) The following are compound average annual rates of change for the aircraft industry from 1972 to 1991:

	Productivity	*Output*	*Employee hours*
1972–91	3.2	4.4	1.2
1973–79	3.8	6.1	2.2
1979–90	.3	1.4	1.2
1990–91	16.8	9.1	– 6.6

Analysis indicates that the lower rate of productivity posted in the latter period was due largely to an unexpected downswing in demand in the early 1980's, interacting with the quasi-fixed nature of labor in aircraft manufacturing, meaning that labor is not easy to downsize in the short term without incurring significant risk.[4] Looking ahead, the certainty of declining demand in the near term has removed much of that risk, so that productivity rates are expected to rise, despite the possibility that output levels may not. Indeed, in the last year for which data are available, 1991, aircraft manufacturing productivity posted a 16.8-percent jump, which exceeded the productivity performance of any published BLS industry for that year.

The aircraft productivity measure was derived by dividing an industry output index series

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by a corresponding BLS-based employee hours index series. The output series was developed from value-of-shipments data reported by the Bureau of the Census. Price changes were removed from the shipments data using price indexes that specifically reflect the price movements of the industry's products over time.[5] Once the annual deflated values or constant-dollar estimates for the industry's product classes were obtained, each was indexed (referenced to a base year) and then multiplied by employee hour weights to derive the overall industry constant-dollar value-of-shipments index series. Finally, the shipments series was adjusted to reflect the net changes in inventories, in order to arrive at a final industry output series.[6]

The reason that aircraft labor appears to be a quasi-fixed factor of production when, normally, labor in manufacturing industries is thought of as a variable factor is embedded in the industry's production processes. One of the ironies about the aircraft industry is that while it makes a high-tech product, it does not rely heavily on high technology for aircraft assembly. As will be explained, this characteristic is unavoidable, given the nature of aircraft manufacturing, which creates several disincentives to the acquisition of labor-saving technology. In addition to the general absence of such technology, the industry combines the quantitative needs of a large manufacturing operation, namely, a massive labor force for production, with the qualitative requirements of a small handcraft shop, which depends on the skill and experience of its workers. The percent of the industry's workers involved in craft and technical jobs is significantly higher than for manufacturing in general, and maintaining enough qualified employees in these positions is one of the industry's chief challenges.

When an aircraft manufacturer hires new workers—sometimes many thousands—it must devote time and money to training them on the numerous complexities involved in building an aircraft and, in the case of the military sector, to obtaining security clearances for some of them. This can amount to a considerable investment. Thus, when a downturn in business occurs, companies tend to be reluctant to reduce their work force immediately. The result is that employment in the industry takes on the characteristics of a quasi-fixed factor in the short run. That is, labor cannot easily be scaled down in the near term without considerable risk, just as is true with such commonly recognized "fixed factors" as machinery or plant capacity. Therefore, downward adjustments in the number of employees and employee hours tend to come slowly, making the natural swings in employee hours lag in the downward direction.

Industry structure

The U.S aircraft industry has four major sectors: the civilian sector, which includes the manufacture of large jet transports and smaller commercial aircraft, known as general-aviation aircraft (jet and propeller-driven planes for business and personal use); the military aircraft sector; a category of establishments that modify, convert, and overhaul used military and civilian aircraft; and a sector that includes those companies which provide research and development and other aerospace services. Historically, the first two sectors have generally accounted for more than 80 percent of the total industry value of shipments.

The industry is characterized by huge capital requirements. Also, in the case of military aircraft, the Department of Defense rates prospective military contractors on the basis of whether they are deemed most capable of meeting its exacting standards, so that applicants lacking significant track records are at a severe disadvantage.[7] Combined, these create formidable barriers to new entrants and promote a high degree of concentration among existing companies. Accordingly, there are only two U.S. manufacturers currently engaged in the production of large commercial jet transports, and while general aviation and the military sector have more companies in them, they are dominated by only a handful of major producers. In 1987, the latest year for which data are available, the four largest aircraft companies accounted for 72 percent of total industry shipments, the largest eight 92 percent. Indeed, 99 percent of the value of all shipments in 1987 was accounted for by the top 20 companies in an industry of approximately 140 companies.[8]

This concentration does not ease competition among the fewer firms, however. Competition in the industry is very fierce, owing both to the billions of dollars that often are at stake with an aircraft contract and to the fact that the industry has relatively few customers. This is particularly true in the military sector, where the U.S. Government is the dominant customer, consuming about 80 percent of domestic military aircraft production. Foreign military sales through the Department of Defense and direct military exports from U.S. producers account for the remaining 20 percent of production.[9]

Behind these relatively few dominant firms is a vast web of subcontractors, both inside and outside the industry, that supply 50 percent or more of the individual components in most military and commercial airframes. Literally thousands of contractors participate in major programs, with the aircraft manufacturer coordinating the supplies and assembling the final product. Not only are small parts such as rivets and spools of wire supplied, but also, entire sections of the aircraft and most of its complicated avionics are often manufactured by suppliers. This large supplier network (3,000 subcontractors for one airframe) contributes to relatively long lead times required between the placement of an order and its delivery. These long lead times often create substantial backlogs that can push delivery dates years into the future, contributing, as will be seen, to various production problems and to burdensome swings in aircraft demand that are characteristic of the industry.

Production methods

As mentioned earlier, although the industry assembles a high-tech product, its assembly process is fairly labor intensive, with relatively little reliance on high-tech production techniques. Several factors account for this. First, the industry assembles a complex and highly customized product. Most commercial aircraft models can be converted into at least three different types: one for passenger service alone, one for a combination of freight and passenger service, and one for freight service alone. Moreover, airlines usually request customized cabin and cockpit configurations and individual paint schemes and may choose different equipment, such as various kinds of engines.[10] This necessitates constant adjustments and retooling on the shop floor, which significantly limits the possibility for substantial automation.

Second, the unit volume of production is very low relative to most manufacturing industries. Total jet transport shipments averaged just 323 units per year during the 1972–91 period. Military shipments averaged 1,246 units.[11] Such a low volume of production makes the automation of many manufacturing processes prohibitively expensive. Even in tedious and repetitive jobs, the justification for investing in a costly robot is often short lived. An example from the early 1980's is a robot one plant considered purchasing to paint aircraft wheel wells for one of its airframes. The plant had only a wing-drilling robot in operation, but the addition of this new robot seemed well justified. The area where the wheel wells were to be painted was cramped, and because it quickly became fogged with paint, a human operator could work only for short periods of time. But while the company was contemplating introducing the device, demand for the airframe slowed, from an already low eight per month to only one or two, and justification for the robot evaporated.[12] These low unit volume levels are a major disincentive to acquiring labor-saving machinery.

Finally, the complexity of the product creates further disincentives to the acquisition of labor-saving machinery. In other manufacturing industries, engineering tolerances might allow fitting errors of as much as one-eighth of an inch or more; similarly, while a surface may require an attractive application of paint, the need for an absolutely consistent coat might be absent. But in a high-performance fighter aircraft, tolerance limits can approach one one-thousandth of an inch, and surfaces must be burnished or painted to perfection. For the fabrication of airplane parts made of composite materials, each layer of the fabriclike material must be laid by hand in a precise pattern over the last, or the structural strength of the part will be compromised. Such demanding tolerances cannot yet be duplicated by a machine without a huge expense, which in most instances would not be cost effective.[13]

Manufacturers are also cautious about the expensive damage that could be caused by a malfunctioning machine. Presently, the entire fuselage of a completed commercial aircraft is polished, first by laborers with power buffers who work an area over and over and then by hand with cheesecloth. This is another laborious process that would clearly benefit from a robot. But the risk of costly damage is too high. If a painting or welding robot on an automobile assembly line malfunctions, the cost of damage done to even several vehicles is small relative to total production. But if a robot punches a hole in a single aircraft fuselage, the expense for rework and repair would be enormous, and even a few small accidents could easily erase the benefit otherwise derived from the machine.[14]

The consequence of these disincentives is that there are only a few industrywide labor-saving technologies currently in place. Wing-drilling/riveting machines are common in the industry, as are conventional numeric control and direct numeric control milling equipment for fabricating some parts. Also, from plant to plant, there are "smaller" technologies that perform various limited functions. For example, in one plant, a computer-operated machine shapes metal hydraulic tubing. In another, a small robot fills empty connector holes in wire harness terminals with plastic insulating plugs. But overall, hand and power tools predominate in an assembly process that requires highly developed production skills from its work force.

Although the plant size of a typical commercial or military aircraft manufacturer is gigantic, the assembly line is, for the most part, not matched by similarly oversized machines. Instead, one sees power drills, wrenches, flashlights, and screwdrivers. Workers stand on scaffolding and bunch around, crouch under, and sit inside the aircraft and its component parts at all stages along the stationary assembly line. (Planes are typically moved to new positions on the shop floor at night.) The production process requires expertise in reading blueprints, proficiency in the use of several different tools, and the ability to anticipate and solve various assembly problems to meet demanding technical standards. Many employees are involved in managing and inspecting the work. For these personnel, well-developed technical skills are essential. Such workers are highly trained and experienced people who cannot easily be replaced.

In addition, the industry requires many more technical nonproduction workers than are typical for manufacturing in general. Experienced engineers in particular are key to firms whose product must attract customers in the highly competitive aircraft market. Like the production workers on the shop floor, these nonproduction workers have skills that are not easily replaced and whose loss could damage a firm's capability of winning contracts in the future.

Employment characteristics

The reliance on a highly skilled work force is reflected in the industry's employment characteristics. Average hourly earnings of production workers in the aircraft industry were significantly above the average of all manufacturing industries over the period measured, ranging from 20 percent higher in 1972 to an estimated 40 percent higher in 1991.[15] These higher earnings support the idea that the skill levels of the workers in this industry are somewhat more advanced than in manufacturing as a whole.

Data on occupations corroborates this idea further. Although occupational data for the aircraft industry alone are not available, data on occupations exist at a somewhat broader level of aggregation, namely, the aircraft and parts group.[16] Precision production, craft, and repair workers accounted for 29 percent of this group in 1990, compared with 21 percent in all manufacturing, while professional and technical workers made up 26 percent of the group, in contrast to total manufacturing's 10 percent. Further, less skilled jobs, such as operators, fabricators, and laborers, accounted for a substantially lower proportion of total employment in the aircraft and parts group, 18 percent, versus the all-manufacturing average of 44 percent.

Total employment in the industry grew at a rate of 1.2 percent from 1972 to 1991. In terms of numbers of employees, this represented a rise from 287,200 to 357,300. Employment peaked in 1989 at 382,200 workers. The number of production workers grew 0.3 percent over the period, while the number of nonproduction workers increased at an average annual rate of 1.9 percent. The proportion of nonproduction workers to total employment moved from 49 percent in 1972 to 57 percent in 1991.

Labor as a quasi-fixed factor

The reliance of the industry on technically skilled employees for production has an impact on productivity at both ends of the industry's demand cycle, but especially during slumps. On the upside of a cycle, less than optimal production levels are initially experienced when the industry hires a relatively new and inexperienced work force to meet increased demand. Long training periods and time on the shop floor are required for the acquisition of the specific skills and knowledge necessary to build the technically advanced aircraft in the industry's commercial and military inventories. A similar result can occur when a company undertakes the assembly of a new airframe. Each airframe assembly requires unique processes and tooling, and workers need time to familiarize themselves with these new techniques.[17]

This situation can be very burdensome to specific plants or sectors of the industry. (It is often the case in the aircraft industry that one sector, such as civilian production, may be growing, while another, such as military production, is in contraction, complicating some industry generalizations.) Much has been written in recent years on various production snags in the commercial sector, on shortcomings in quality that have required costly rework and repair, and on delivery delays caused by rapidly expanding numbers of new hires in the late 1980's.[18] One aircraft company doubled the number of workers in its ranks,[19] while another's labor force increased 86 percent in 5 years.[20] At the time, some analysts even hinted that the production problems brought on by this new work force might torpedo the very recovery that had fueled the massive hiring in the first place.[21]

These are among the reasons that aircraft companies are reluctant to scale down their work forces significantly during a slump. And besides the reduced efficiency resulting from such downsizing, firms must contend with the many assembly errors a novice work force is prone to, which can be very costly for manufacturers in terms of employee hours. For example, a seasoned work force assembling an established model might put only 10 percent of its total employee hours into reworking mistakes or problems, whereas a newly hired staff can expend as much as 60 percent of its total hours in this nonadditive labor.[22] (Even with an experienced work force, reworking is often the chief driver in employee-hour costs for a new model.)[23] Accordingly, a plant that scales down its work force too quickly during a slump risks losing skilled employees and may experience production slowdowns that, given the industry's highly competitive environment, can adversely affect its ability to win customers.[24] In sum, aircraft manufacturing is a long-term proposition. Particular models of military and, especially, commercial aircraft may be in production for many years, with the life of the aircraft continuing a company's involvement with a production program for still more years or even decades. Thus, manufacturers would be hurt, rather than helped, if they reacted to short-term cycles.[25]

In addition, by immediately reacting to a softening of demand by downsizing their work forces, manufacturers risk the often considerable investment of the time and money spent to train new employees. Training periods can last as long as 5 weeks for some jobs. In the case of a company that is doubling its work force, this represents a significant financial investment that would probably be lost if workers were laid off quickly and en masse, as they sometimes are in other manufacturing industries.[26]

With regard to the military sector, there is the additional investment of gaining security clearances for workers on certain programs. Security clearances are difficult to obtain and require manufacturers to undergo a laborious process in getting them. Any number of factors can delay or invalidate a worker's clearance, making it hard for manufacturers to maintain an adequate pool of "cleared" employees. As a consequence, military firms will move these employees around in the short run, even into jobs not directly related to manufacturing, in order to retain them. Even a layoff of short duration often requires the company to start the security clearance process over again when the employee is called back. Thus, airframe painters might be shifted to painting areas of the plant, and skilled assemblers, while retaining their high salaries, might be assigned to plant maintenance tasks. One military aircraft company reports that it is very conservative in hiring maintenance workers for this very reason: to have a function, albeit a nonmanufacturing one, for its production workers during short-term slowdowns.[27]

The result of all these factors is that labor in the industry tends to be a quasi-fixed factor in the short run, as costly to reduce as such "fixed factors" of production as machinery and plant capacity.[28] Like one of these fixed factors, skilled labor becomes an investment that manufacturers can adjust downward in the short term only at a considerable cost.[29]

The aircraft market

The tendency for adjustments to the aircraft labor force to lag in the downward direction is exacerbated by the nature of the industry's market. The aircraft market is extremely volatile. It responds slowly to changes in the general economy and is characterized by sudden and often unpredictable swings in demand.[30] In the military sector of the industry, demand is shaped by the confluence of world events, evolving military strategies, economic factors, and a changeable political climate. In the jet transport sector, wide swings in demand are built into the market, because of an imbalance between passenger demand and available airplane seats. Passenger demand grows at a certain rate, while the number of available seats at any particular time is fixed. Consequently, airlines faced with too little capacity will order new planes, often creating more available seats than the current passenger demand warrants. New orders then slow, and the market tips in the other direction until the volume of traffic catches up and airline capacity once again is exceeded.[31]

In the commercial sector, this swing in demand can be multiplied by the long lead times often required for delivery of commercial aircraft. When the sector as a whole enters a period during which passenger demand either exceeds or is expected to exceed capacity, a frenzy of buying can occur, as individual companies fear being locked out by their competitors.[32] (For example, an airline ordering a plane in 1990, in the midst of the last buying frenzy, would have had to wait as long as 7 years for delivery.) The result of a buying frenzy is that, with all the airlines suddenly ordering new planes, the skies become glutted with available seats—especially if passenger growth falls short of estimates—and future aircraft output then suffers. This is why, in the commercial market, a feast in new demand is traditionally followed by famine, which is what happened between 1979 and 1990. Coupled with the quasi-fixed nature of labor in aircraft manufacturing, the feast and famine cycle helps explain why productivity growth averaged only 0.3 percent during that period.

The 1979–90 period[33]

At the end of the 1970's, demand for fuel-efficient aircraft and published projections of airline-passenger growth rates of 6.6 percent a year started a scramble for new aircraft that swelled manufacturers' order books. A then-record number of 516 aircraft were ordered in 1978.[34] By 1979, when output jumped 24.6 percent, production lines were rolling, and 376 large transports were delivered, a number that was up 135 units from the 241 delivered the previous year.[35] Projections remained optimistic, and the commercial sector was gearing up for a bright future. But a sluggish world economy at the start of 1980 caused the growth in the number of passengers to slow, and the skies suddenly filled with excess capacity. An estimated equivalent of 21 empty wide-body aircraft flew the Atlantic each day during the summer of 1980. The next year, more than 20 completed aircraft were delivered directly into storage because an immediate need for their use no longer existed. In this suddenly chilled economic environment, falling fuel prices withered aircraft demand further by removing the stimulus for more fuel-efficient planes, and airline deregulation brought on the additional burden of uncertainty. Anxious airlines put unwanted aircraft for sale onto the world market and began canceling orders. After the delivery of 387 large transports to customers in 1980, production fell every year through 1984, when only 185 new planes were delivered.

General aviation, another segment of the civilian sector, encountered similar unexpected problems that sent it spiraling. Like those in the large-transport sector, manufacturers of general-aviation aircraft were optimistic about the near future at the start of the 1980's. In 1978, a record 17,817 general-aviation airplanes were produced. But a series of product liability suits resulting from crashes of general-aviation aircraft in the late 1970's all but bankrupted the production of light, piston-driven aircraft. The average cost of product liability insurance rocketed upward, from roughly $51 per plane in 1962 to $100,000 for each aircraft in 1988. Part of this cost had to be passed on to the individual consumers who purchase airplanes, making the product too expensive for many customers and causing them to look to foreign manufacturers. As a result, U.S. production rates plummeted. From the 17,817 general-aviation aircraft produced in 1978, production fell to 9,457 units in 1981. That year, imports of general-aviation aircraft exceeded exports for the first time, making general aviation the only segment of the aerospace industry with a trade deficit. The slide continued. In 1988, when the general-aviation trade imbalance grew to $1 billion, only 1,143 units were sold, and today, it is estimated that barely more than 800 general-aviation aircraft are in production in U.S. plants. Foreign companies are liable under U.S. tort law, but only for those planes sold to the United States, and, because the foreign airplane fleet is significantly newer than the U.S.-produced fleet, insurance rates are usually much lower for foreign manufacturers. (Manufacturers are responsible for all of their aircraft in flight in the United States; in the case of U.S. producers, these include aircraft as old as 30 years.)

The downward pressures on the civilian sector were evident in industry statistics starting in 1981, when output fell 1.2 percent. The downturn continued in 1982, with a drop of 10.2 percent, then in 1983, with a drop of 14.8 percent, and finally, in 1984, with a 4.9-percent decline. The military sector fared much better during this period, but because of the high cost of jet transports, changes in commercial production rates have a greater impact on industry output trends than do similar changes in the military sector, so industry trends tend to be led by the commercial sector.[36]

For most of the 1979–90 period, and especially during the downturn in the early 1980's, employee hour movements characteristic of a quasi-fixed factor of production are evident. The year that starts the period, 1979, saw output rise 24.6 percent from the previous year. Employment rose 15.6 percent and employee hours increased 16.0 percent, leading to a productivity growth of 7.5 percent. In 1980, output grew again, by 2.2 percent, but employee hours grew more, making it the first year in the period when productivity fell (–1.9 percent) and perhaps illustrating the initial increase in hours that can occur when the industry brings in many new employees. (From 1978 to 1980, employment grew by 61,000.) When, in 1981, output took its first dip, employment and hours also dropped, and productivity advanced 0.9 percent. But thereafter, the reductions in employees and hours never kept pace with the declining output. (See table 1.) When output fell 10.2 percent in 1982, employee hours shrank a smaller 7.5 percent. When the industry's output fell a further 14.8 percent the next year, hours again fell, but by a far lesser 4.9 percent, leading to a 10.4-percent drop in productivity, the worst performance in aircraft manufacturing of any year in the study. Manufacturers, remaining optimistic that an upswing was soon coming, did not want to scale back quickly on the large investment in new workers that they had made only a few years earlier. Then, in 1984, the number of new orders began to rise. Because of the long lead times required, manufacturers started to gear up for the future. So, even though output for that year fell almost 5 percent, employment and employee hours edged up, resulting in a 5.8-percent decline in productivity. The next year, 1985, output jumped 18 percent, employee hours rose 6.7 percent, and productivity registered a 10.7-percent gain.

The earlier period, 1973 to 1979, showed similar movements. Output fell 3.2 percent in 1975 and 6.0 percent in 1976. Like the downswing in the 1980's, employee hours at first matched the drop in output, shrinking 3.5 percent in 1975. The result was a slight, 0.2-percent increase in productivity that year. But during the following year, even though output dropped 6.0 percent, orders were beginning to pick up. Manufacturers could not afford to cut employment by amounts dictated by a purely short-term analysis. Consequently, employee hours dropped 4.2 percent, and productivity suffered, slipping almost 2 percent. The next year, 1977, output bounced back 7.2 percent, and productivity grew nearly 11 percent.

Overall, output fell seven times in aircraft manufacturing during the period covered by the study. In 5 of those years, productivity suffered, either because employee hours fell by less than output or, in the case of 1984, when manufacturers were gearing up for the future, because employee hours actually rose. By contrast, in the total manufacturing sector, output fell four times in the 1972–88 period (1988 is the last year for which comparable data are available), and productivity registered gains in each case, as employee hours always fell by a greater percentage than output.

Outlook

On the surface, the early 1990's appear to be moving toward a repeat of the slow growth in productivity during the 1980's. Like the early 1980's, the early 1990's were preceded by a burst in the number of orders of jet transports and a swelling confidence about the future. And like the 1979–90 period, after significant investments in labor, the early 1990's have seen new orders wither and old orders disappear in a wave of cancellations and delivery delays, while the general assessment of long-term commercial growth remains positive. The recent scaling back of the military sector also appears in some ways an echo of that earlier period. So, given the quasi-fixed nature of aircraft labor, is the future likely to see another stretch of poor productivity performance in aircraft manufacturing? Evidence suggests that the answer is no.

Table 1. **Productivity and related indexes for the aircraft industry, 1972–91**

[1982 = 100]

Year	Outper per employee hour	Output	All employee hours	Production worker hours	Nonproduction worker hours
1972	69.3	61.7	89.0	95.4	83.7
1973	83.1	77.4	93.1	100.3	87.0
1974	84.8	81.1	95.6	103.8	88.7
1975	85.0	78.5	92.3	98.1	87.5
1976	83.5	73.8	88.4	92.0	85.4
1977	92.5	79.1	85.5	88.1	83.3
1978	96.9	88.6	91.4	95.3	88.1
1979	104.2	110.4	106.0	118.6	95.5
1980	102.2	112.8	110.4	122.7	100.2
1981	103.1	111.4	108.1	116.5	101.1
1982	100.0	100.0	100.0	100.0	100.0
1983	89.6	85.2	95.1	90.7	98.9
1984	84.4	81.0	96.0	89.2	101.5
1985	93.4	95.6	102.4	95.0	108.5
1986	93.4	100.2	107.3	104.3	109.8
1987	101.2	114.2	112.9	113.2	112.6
1988	104.1	121.4	116.6	115.0	117.8
1989	107.9	129.6	120.1	117.1	122.6
1990	107.4	129.2	120.3	116.2	123.8
1991	125.4	140.9	112.4	106.9	117.0

First, it is commonly assumed that the downsizing of the military sector will be of a sustained and substantial magnitude. With the breakup of the Soviet Union, the military sector's primary preoccupation is with streamlining. The era of large military buildups appears over. Business survival in the decade ahead will be measured by how successfully firms can build down.[37] The short-term risk in laying off employees is outweighed by the near certainty of this downward long-term trend. As a result, the lagging characteristics of aircraft labor in the downward direction have not been observed recently in the military sector. Starting in early 1990, when 55,000 employees were released, manufacturers of military aircraft continued shedding workers. Some companies were holding onto employees while one particularly large contract was under competition. But when it was awarded, the companies that lost the contract immediately announced layoffs amounting to several thousand workers.[38] There is now a general acceptance among military aircraft manufacturers that the historically "cyclical defense-spending upturns" are over.[39] As a result, with many fixed assets being closed, the hesitation to cut employees will be greatly reduced, and whatever negative impact it had on past productivity performance in the military sector should be minimized.

Similarly, general-aviation productivity should not suffer from any reluctance to reduce labor ranks for the same reasons: manufacturers' diminished expectations for the future are relatively certain. Product liability problems continue to cripple piston-engine production. As a result, the general-aviation product mix has shifted, and more than 90 percent of the dollar value for U.S.-manufactured fixed-wing aircraft is for turboprop and turbofan business aircraft. In this area at least, the improving economy might eventually lead to an increase in demand as corporate fleets grow.[40] But it is unlikely that this potential stimulus would increase production rates significantly. In any case, the impact on total industry productivity would be negligible: today, general-aviation production has become so small a part of the industry, that it affects industry productivity trends only slightly.

So, as was true in the 1980's, it appears that the future of productivity in the aircraft industry rests primarily with what happens in the commercial sector. One of the most worrisome factors in regard to aircraft labor's tendency to be slow to adjust downward is that commercial production is facing a sharp dichotomy between prospects for strong output growth in the long run and weakened demand in the near term.

There are different reasons for this situation. First, many industry analysts predict that upwards of 300 planes a year will be retired during the 1990's because of their age or to meet noise restrictions that go into effect by the year 2000. Currently, this affects nearly one-half of the world's fleet of planes, with one-half of those used by U.S. companies.

Second, demand is also expected to get a boost from the growth in airline traffic from the Pacific rim. Worldwide, the top three growth markets for the 1990's are Asian related, with an average passenger growth rate of 10.6 percent.[41] This rate should lead to a doubling of air travel by the year 2000 and a quadrupling 15 years later.[42] One estimate has it that, by the year 2000, 40 percent of all airline passengers will fly on Asian carriers.[43] It is predicted that, taken together, the dual pressures of the aging U.S. airline fleet and ever-growing passenger traffic will require the production of more than 11,000 new aircraft, most wide bodied, over the next 20 years.[44] This is why, observed one analyst early last year, the "world's civil aircraft manufacturers are keeping design teams and production lines busy, even in hard times."[45]

This holding the line is possible, in part, because commercial manufacturers are intent not to repeat the mistake of expanding output so quickly. Hence, despite the flood of new orders they received in the late 1980's, they chose to allow backlogs to grow, focusing on establishing an efficient production rate that could carry them through a potential future downswing.[46]

Nevertheless, manufacturers of jet transports, like their counterparts in military and general aviation production, now realize that the near future will likely be lean. A recent study[47] suggests that it will be close to the turn of the century before the industry returns to its 1991 level of business and that the industry will not bottom out until 1996. Given this projection, jet transport manufacturers, too, have shown less hesitation than in the past to cut employees and trim employee hours.[48] As a result, the number of employees dropped 6 percent and employee hours dropped almost 7 percent in 1991, the second largest drop for both over the period covered by the study. (The largest drop occurred in 1982, in the midst of the industry's recession.) It appears that, with some of the uncertainty removed about the direction of aircraft demand in the next several years, labor may be taking on the characteristics of a variable factor, at least in the near term.

Because of this shift, with the entrance of some computer-aided technology, the industry should post strong productivity gains in the decade ahead. Already, it has registered a 16.8-percent gain in productivity in 1991. The diffusion of computer-aided design technology, perhaps more descriptively called "paperless design," may also affect productivity gains. Given the fact that nearly a million separate sheets of blueprint paper accompany the design and production of a conventional aircraft, this new application of computer-aided design technology may revolutionize the way planes are designed and initially constructed.[49] First used on a full scale in the design of the B–2 stealth bomber, paperless design allowed manufacturers to go directly from the computerized "drawing board" to the first flyable plane, without all of the many intervening models and mockups that would have had to be made in the past. All but 3 percent of the computer-aided manufactured parts fit perfectly the first time, compared with the best ever 50 percent achieved by the same company using conventional pen-and-paper methods. It is claimed that there was a 6-to-1 reduction in engineering changes during the B–2's design evolution, and those changes were made 5 times faster and could be inputted into both manual and computerized numeric-control milling machines 40 percent more efficiently.[50] The technology is now being adopted in the commercial sector, and if it lives up to expectations, it will save the thousands of hours of labor that go into the old pen-and-paper design of new airframes and the construction of wood and metal life-size mockups.

The value of paperless design to production later on in an airframe's life may be less dramatic.[51] Nevertheless, the estimated savings of 60 percent of the engineering changes in an industry with a high proportion of engineers and related nonproduction workers will certainly contribute to productivity gains. □

Footnotes

[1] See Jeffery Cole, "Boeing Gets New Demand from United Seeking Change in Delivery of Jetliners," *Aviation Week & Space Technology*, Feb. 11, 1993, p. A3; John D. Morrocco, "Aspin to Chart Defense Draw Down," *Aviation Week & Space Technology*, Jan. 4, 1993, p. 28; Jeff Cole, "GPA Wins Pact on Order Cuts from Jet Firms," *The Wall Street Journal*, Jan. 25, 1993, pp. A3, A5; Jeff Cole, "McDonnell to Cut 10% of Work Force, Many at Its Commercial Aircraft Unit," *The Wall Street Journal*, Jan. 25, 1993, p. A5; Richard M. Weintraub, "Boeing, Pratt & Whitney Plan Huge Job Cutbacks," *The Washington Post*, Jan. 27, 1993, pp. F1, F3; and Jeff Cole, "Boeing Reduces Its Production of All Jetliners," *The Wall Street Journal*, Jan. 27, 1993, pp. A3, A5.

[2] See *Standard and Poor's Industry Surveys*, "Aerospace and Air Transportation: Basic Analysis," July 25, 1992, p. A15; and International Trade Administration, U.S. Department of Commerce, *1993 U.S. Industrial Outlook* (Washington, U.S. Government Printing Office, January 1993), pp. 20–27.

[3] The aircraft industry is designated by the Office of Management and Budget as SIC 3721 in the 1987 *Standard In-*

dustrial Classification Manual. This industry comprises establishments engaged primarily in the manufacture of completed aircraft. Establishments engaged primarily in manufacturing engines and other aircraft parts and auxiliary equipment are classified into SIC's 3724 and 3728.

The average annual rates of change in the text are computed using the compound rate formula. These rates reflect the average rates of growth between beginning and ending years. For comparisons among periods, peak years in the business cycle were chosen as the beginning and ending years.

Extensions of the indexes will appear annually in the BLS bulletin, *Productivity Measures for Selected Industries and Government Services.* A technical note describing the methods used to develop the indexes is available from the Bureau's Office of Productivity and Technology, Division of Industry Productivity and Technology Studies.

[4] Walter Y. Oi, "Labor as a Quasi-Fixed Factor," *Journal of Political Economy*, December 1962, pp. 538–55.

[5] The price indexes for the aircraft industry's products were developed from data from three different government agencies. For years prior to 1987, the indexes were constructed from data from the Bureau of Labor Statistics, Bureau of Economic Analysis, and Federal Aviation Administration. For years since 1987, the indexes were derived from information from the Bureau of Labor Statistics alone. Depending upon each agency's objectives and the use to which they envisioned that their data would be employed, different methodologies were used to develop measures of price change. For example, there were differences in such price-defining characteristics as production-run size, production rate, position on learning curve, and differential-cost structures among producers.

[6] See appendix for a fuller discussion of the methodology.

[7] *Standard and Poor's Industry Surveys*, "Aerospace and Air Transportation: Basic Analysis," July 25, 1992, p. A17.

[8] *1987 Census of Manufactures, Concentration Ratios in Manufacturing*, MC87–S–6 (U.S. Department of Commerce, Bureau of the Census, February 1992), pp. 6–39.

[9] International Trade Administration, *1993 U.S. Industrial Outlook*, pp. 20–29.

[10] Bruce A. Smith, "Douglas Speeds MD–11 Production with New Management System," *Aviation Week & Space Technology*, Sept. 9, 1991, p. 42.

[11] International Trade Administration, *1993 U.S. Industrial Outlook*, pp. 20–28.

[12] Richard G. O'Lone, "Boeing Approaches Robots Cautiously," *Aviation Week & Space Technology*, Aug. 2, 1982, p. 60.

[13] Industry source.

[14] O'Lone, "Boeing Approaches," p. 60.

[15] Current data on average hourly earnings for production workers are not available for the aircraft industry (SIC 3721). Consequently, data for the aircraft and parts industry (SIC 372) have been used for the 1991 estimate.

[16] *BLS Industry-Occupational Employment Matrix, 1990*, "Projected 2005 Alternatives," pp. 160–69, 498–504; *Outlook 1990-2005*, Bulletin 2402 (Bureau of Labor Statistics, May 1992); and unpublished data.

[17] Richard G. O'Lone, "U.S. Manufacturers Expect Strong Long-Range Demand," *Aviation Week & Space Technology*, Mar. 19, 1990, p. 105; and industry sources.

[18] See Richard W. Stevenson, "Battling the Lethargy at Douglas," *New York Times*, July 22, 1990, Section 3, pp. 1–6; "How Boeing Does It," *Business Week*, July 9, 1990, p. 50; Anthony Ramirez, "Boeing's Happy, Harrowing Times," *Fortune*, July 17, 1989, pp. 40–48; "Boeing Sets Delivery Plan," *New York Times*, May 10, 1989, p. D42; James Ellis, "McDonnell Douglas: An Order Boom, but an Operating Loss," Maria Shao, "Boeing: A Backlog Strains Its Assembly Line," and Stewart Toy and John Templeman, "Airbus: Still in the Red Despite Subsidies," all in "Planemakers Have It So Good, It's Bad," *Business Week*, May 8, 1989, pp. 34–36; Ronald Henkoff, "Bumpy Flight at McDonnell Douglas," *Fortune*, Aug. 28, 1989, pp. 79–80; and Bruce A. Smith, "Douglas Grapples with Delays in Three Transport Programs," *Aviation Week & Space Technology*, Apr. 10, 1989, pp. 88–89.

[19] Ellis, "McDonnell Douglas," p. 34.

[20] Shao, "Boeing," p. 36.

[21] Ellis, "McDonnell Douglas," pp. 34–35; Shao, "Boeing," pp. 35–36; and Toy and Templeman, "Airbus," p. 36.

[22] Industry sources.

[23] Richard G. O'Lone, "777 Revolutionizes Boeing Aircraft Development Process," *Aviation Week & Space Technology*, June 3, 1991, p. 35.

[24] See Jeffery M. Lenorovitz, "Airbus Expects to Boost Market Share to 30%," *Aviation Week & Space Technology*, Mar. 19, 1990, p. 123; and Lawrence M. Fisher, "Boeing Challenged by Its Backlog," *New York Times*, Dec. 7, 1988, p. D5.

[25] Bruce A. Smith, "Boeing to Rely on Proven Strategies while Facing Prospect of Lower Earnings," *Aviation Week & Space Technology*, May 25, 1992, p. 65.

[26] Oi, "Labor as Quasi-Fixed," p. 542.

[27] Industry sources.

[28] Oi, "Labor as Quasi-Fixed," pp. 538–45.

[29] Virginia Lopez, ed., *Productivity in the U.S. Aerospace Industry: 1960–1978* (Washington, The Aerospace Research Center, Aerospace Industries Association of America, Inc., December 1980), p. 36.

[30] See U.S. Department of Commerce, International Trade Administration, *1977 U.S. Industrial Outlook* (Washington, U.S. Government Printing Office, 1977), p. 184; and *Standard and Poor's Industry Surveys*, "Aerospace and Air Transportation," Dec. 1, 1983, p. A16.

[31] Ramirez, "Boeing's Times," p. 40.

[32] Richard G. O'Lone, "Commercial Airframe Makers Take Conservative Approach," *Aviation Week & Space Technology*, Mar. 20, 1989, pp. 197–99.

[33] Unless otherwise specified, the information in this section was derived from the chapter on the aerospace industry in the annual *U.S. Industrial Outlook*, published by the U.S. Department of Commerce, International Trade Administration (Washington, U.S. Government Printing Office, 1980 through 1993 editions).

[34] Aerospace Industries Association, *Net New Firm Orders Booked for U.S. Civilian Jet Transport Aircraft, 1971–1981*, unpublished.

[35] *Aerospace Facts & Figures, 1992–93* (Washington, Aerospace Industries Association, 1992), p. 32.

[36] Industry sources.

[37] See John D. Morrocco, "Uncertain U.S. Military Needs Hamper Industry Restructuring," *Aviation Week & Space Technology*, June 17, 1991, pp. 62–66; and "Cheney's 25% Force Reduction Plan Could Spur Further Spending Cuts," *Aviation Week & Space Technology*, June 25, 1990, pp. 24–25; see also Janice Castro, "Biting the Bullets," *Time*, Apr. 30, 1990, pp. 69–71; and "Victims of Peace," *The Economist*, June 10, 1989, pp. 61–62.

[38] "Recession, Military Reductions Force U.S. Aerospace Firms to Cut Payrolls," *Aviation Week & Space Technology*, Mar. 4, 1991, pp. 52–55.

[39] Anthony L. Velocci, Jr., "Survival Strategies for the 1990s," *Aviation Week & Space Technology*, May 25, 1992, p. 38.

[40] *Standard and Poor's Industrial Surveys*, "Aerospace and Air Transportation," June 25, 1992, p. A22.

[41] Richard G. O'Lone, "Boeing Expects War, Economic Dip to Have Minimal Impact on World Transport Market," *Aviation Week & Space Technology*, Mar. 4, 1991, p. 33.

[42] Anthony L. Velocci, Jr., "Industry May Endure a Decade of Hardship," *Aviation Week & Space Technology*, Nov. 23, 1992, p. 27.

[43] Paul Proctor, "Growing Economies, New Airports Stoke Pacific Rim Transport Boom," *Aviation Week & Space Technology*, June 17, 1991, pp. 117–20.

[44] Velocci, "Survival Strategies," p. 38.

[45] Richard G. O'Lone, "U.S. Airframe Outlook Bright despite Gloomy 1991 Results," *Aviation Week & Space Technology*, Mar. 16, 1992, p. 53.

[46] Smith, "Boeing to Rely on Proven Strategies," pp. 63–66.

[47] Quoted in Velocci, "Industry May Endure," p. 26.

[48] Cole, "Boeing Reduces Its Production," pp. A3–A5; and "Boeing Cuts Rates Again," *Aviation Week & Space Technology*, Nov. 30, 1992, p. 32.

[49] See David Hughes, "Growing Use of CAD/CAM Workstations Leading to Paperless Design Process," *Aviation Week & Space Technology*, Aug. 19, 1991, pp. 44–46; Bruce D. Nordwall, "McDonnell Will Replace Workstations to Gain Flexibility and Solid Models," *Aviation Week & Space Technology*, Aug. 19, 1991, pp. 49–50; and "Aerospace Manufacturers Exploit Workstation Network Capabilities," *Aviation Week & Space Technology*, Aug. 19, 1991, pp. 47–48; and Breck W. Henderson, "Workstation Performance Expands as Technology Pushes Prices Lower," *Aviation Week & Space Technology*, Aug. 19, 1991, pp. 51–53; and "Smart Factories: America's Turn?" *Business Week*, May 8, 1989, pp. 142–48.

[50] "Computer System Design Reflects B-2's Complexity," *Aviation Week & Space Technology*, Nov. 28, 1988, pp. 26–27.

[51] "Plane Geometry," *Scientific American*, March 1991, pp. 110–11.

APPENDIX: Measurement techniques and limitations

Indexes of output per employee hour measure changes in the relation between the output of an industry and the employee hours expended in producing that output. An index of output per employee hour is derived by dividing an index of output by an index of industry employee hours.

The preferred output index for manufacturing industries would be obtained from data on quantities of the various goods produced by the industry, each weighted (multiplied) by the employee hours required to produce one unit of each good in some specified base period. Thus, those goods which require more labor for production are given more importance in the index.

In the absence of a comprehensive set of unit employee hour weights, or equivalently, unit values, the output index for the aircraft manufacturing industry was developed using a deflated value technique. The values of shipments of the various product classes were adjusted for price changes by appropriate price indexes from a variety of sources, including (1) Producer Price Indexes from the Bureau of Labor Statistics; (2) indexes from the Price Change of Defense Purchases program, a project of the Bureau of Economic Analysis; and (3) unpublished data from the Federal Aviation Administration. These estimates of real or constant dollars for product categories were then indexed and, in turn, combined with employee hour weights to derive the overall industry output measure. The result is a final output index that is conceptually close to the preferred output measure.

The annual output index series was than adjusted (by linear interpolation) to the index levels of the benchmark output series. This benchmark series incorporates more comprehensive, but less frequently collected, economic census data.

The employment and employee hours indexes used to measure labor input were derived from data published by the Bureau of Labor Statistics. Employees and employee hours are each considered homogeneous and additive and thus do not reflect changes in qualitative aspects of labor, such as skill and experience. The indexes of output per employee hour do not measure any specific contributions, such as those of labor or capital. Rather, they reflect the joint effect of such factors as changes in technology, capital investment, capacity utilization, plant design and layout, skill and effort of the work force, managerial ability, and labor-management relations.