Productivity in scrap and waste materials processing

Higher capacity machinery, growing demand, and industry consolidation spurred gains in output per hour of all persons over the 1977–87 period

Mark Scott Sieling

Changes in demand and output, processing machinery, and industry structure helped spur long-term productivity gains in the scrap and waste materials industry. A Bureau of Labor Statistics new measure of industry productivity shows that output per hour of all persons in the industry increased at an average annual rate of 3.0 percent between 1977 and 1987, identical to the rate for all manufacturing industries combined.[1] The all person hours index declined 1.2 percent a year, while output increased 1.7 percent. (See table 1.)

The demand for processed scrap and waste materials increased over the 1977–87 period due to growing exports and changes in steel and paper manufacturing processes, while increased recycling efforts made more unprocessed scrap and waste materials available. The installation of higher capacity processing equipment and a reduction in the number of marginal processing establishments (typically small-size firms) also spurred productivity gains over the period, especially since the early 1980's.

Average annual productivity gains varied considerably over shorter periods. For example, from 1977 to 1980, output per hour of all persons increased at an average annual rate of 2.4 percent, with output increasing faster than all person hours—5.7 percent, compared with 3.2 percent. These trends, however, were reversed during the 1980–82 period, when output per hour of all persons declined 2.4 percent a year, as output declined faster than hours and employment. Between 1980 and 1982, output fell by about one-fifth, as domestic and foreign demand shrank, while hours and employment each declined by about one-sixth.

Since 1982, improvements in processing technologies and machinery as well as continued strong demand for scrap metal and wastepaper contributed to above-average productivity gains. Over the 1982–87 period, output per hour of all persons increased by an average 5.2 percent per year, compared with a 4.5-percent annual increase for all manufacturing combined. Output increased 7.1 percent per year, overshadowing average annual increases in hours (1.8 percent) and employment (1.4 percent).

Year-to-year productivity changes reflected swings in demand, output, and other factors. For example, between 1982 and 1983, output per hour of all persons increased 19.9 percent. Output increased by 14 percent, reflecting strong foreign and domestic demand, while hours and employment declined because a large number of small-size establishments left the industry (primarily as a result of the 1981–82 recession).[2] In contrast, output per hour declined 0.1 percent between 1978 and 1979, as output, hours, and employment all increased by about 10 percent.

Output and demand

The scrap and waste materials industry processes a variety of materials, from scrap copper and gold to rags and fur cuttings. However,

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Table 1. **Productivity and related indexes in the scrap and waste materials industry, 1977–87**

[1977=100]

Year	Output per hour of all persons	Output	Hours of all persons	All persons
1977	100.0	100.0	100.0	100.0
1978	110.7	108.9	98.4	98.0
1979	110.6	120.6	109.0	108.3
1980	108.2	116.2	107.4	109.0
1981	104.8	109.7	104.7	104.6
1982	103.0	92.5	89.8	91.7
1983	123.5	105.5	85.4	85.6
1984	122.2	114.7	93.9	94.3
1985	127.9	118.2	92.4	93.5
1986	133.8	124.0	92.7	92.5
1987	138.7	135.1	97.4	96.8
	Average annual rates of change (in percent)			
1977–82	−.1	−1.2	−1.0	−.7
1982–87	5.2	7.1	1.8	1.4
1977–87	3.0	1.7	−1.2	−1.2

ferrous scrap metal and wastepaper represent the bulk of the industry's output. In 1982, ferrous scrap tonnage accounted for about nine-tenths of total metal scrap processed by the industry, while wastepaper tonnage accounted for about three-fourths of total nonmetallic waste.[3]

Scrap ferrous metal processors and dealers collect scrap such as junked autos, old equipment, steel from obsolete buildings, and waste from metalworking industries. They sort this "obsolete scrap" into one of more than 80 separate scrap metal grades, then process it into forms usable by steel manufacturers and foundries.[4] Obsolete scrap is a primary feedstock for iron and steel manufacturing and foundry operations, along with pig iron, directly reduced iron ore, and "home scrap"—scrap generated by steel and iron manufacturing operations and metalworking industries.

A number of factors influence the demand for, and output of, obsolete ferrous scrap. Traditionally, demand has closely reflected the level of domestic and foreign steel and iron manufacturing.[5] But recent changes in steelmaking technology have partially broken that bond.

Between 1977 and 1987, shifts and changes in steel manufacturing techniques, such as the increased use of electric arc furnaces which primarily use scrap as a feedstock, spurred demand for processed obsolete scrap.[6] Although the production of primary iron and steel fell by about one-third over this period, domestic consumption of obsolete scrap increased from 38 million tons to 42 million tons.[7]

Reductions in the production of home scrap also influenced the demand for obsolete scrap. Because of improvements in steel manufacturing, such as continuous casting and improved metalworking technologies, as well as the closing of older, less efficient steel mills which traditionally produced large amounts of home scrap, the output of home scrap fell from just under 50 million tons in 1977 to 25 million tons in 1987.[8] This 50-percent reduction in the production of home scrap, combined with the increasing use of scrap in basic iron and steel manufacturing, led to greater demand for obsolete scrap.

Although the output of obsolete ferrous scrap increased over the 1977–87 period, the industry still maintained a processing capacity far in excess of demand. For example, in 1984, the industry's processing capacity was 130 million tons: it actually produced about 49 million tons.[9] This gap between capacity and actual production partially reflects demand factors and the industry's traditional one-shift-per-day operations.[10]

While overall output of obsolete scrap increased between 1977 and 1987, there were significant regional variations. Generally, output of ferrous scrap in the Great Lakes, Midwest, and Northeast regions declined, as steel mills closed. Output increased in the South, Southwest, and West, largely attributable to the growth of minimills which rely heavily on scrap as their primary feedstock.[11] It should be noted that most scrap processors are in close proximity to their customers, mainly because of transportation costs.[12] However, long distance trade among States, regions, and countries does occur, and in some cases, increases in foreign demand have compensated for declining local demand.

In addition to the increase in domestic consumption of obsolete scrap, foreign consumption of U.S. ferrous scrap rose significantly between 1977 and 1987. In 1977, exports totaled 5.9 million tons or about one-eighth of total obsolete scrap produced; by 1987, exports had grown to 10.4 million tons, representing one-fifth of total production.[13]

Regardless of the changes in basic steel manufacturing technologies that have influenced the long-term demand for obsolete ferrous scrap, year-to-year changes in domestic steel production still strongly affect the output of obsolete scrap. Between 1986 and 1987, both raw steel and obsolete scrap production increased by 8 percent; between 1981 and 1982, domestic shipments of obsolete scrap dropped 31 percent,

primarily reflecting a 38-percent decline in steel production.

Wastepaper processors collect various types of used paper products such as newspapers, business and computer paper, and corrugated boxes. They sort them into one of 70 separate grades, then bundle them for use by paper mills and building supply manufacturers. Between 1977 and 1987, the annual domestic consumption of wastepaper increased from 15 million tons to 20 million tons; exports more than doubled from 1.9 million tons to 4.4 million tons.

About one-third of the approximately 600 paper and pulp mills in the United States use processed wastepaper products as their primary feedstock. In an additional 300 mills, recycled fibers account for 15 percent to 25 percent of the feedstock.[14] (It should be noted that large integrated paper mills usually cannot substitute wastepaper for woodpulp in the manufacturing process.[15])

Foreign consumption of U.S. ferrous scrap rose significantly between 1977 and 1987.

During the 1977–87 period, corrugated scrap annually accounted for between two-fifths and one-half of total wastepaper output; newspaper and mixed grade waste each accounted for about one-sixth; and high grade de-inked and pulp substitutes, such as brown paper bags and computer and ledger paper, for one-fifth.[16] In most cases, the proportion of processed wastepaper used in manufacturing various paper products increased significantly between 1977 and 1987. In 1977, wastepaper feedstocks accounted for just over 15 percent of total newspaper production; by 1986, the proportion had risen to 27 percent. A similar increase was recorded for tissue paper, which used just over 40 percent wastepaper feedstock in 1987, compared with 28 percent in 1977. Manufacturers of kraft paperboard, however, only moderately increased their use of wastepaper feedstocks, from 4.2 percent to 7.9 percent.[17]

Because there is some substitution between woodpulp and wastepaper, yearly demand for wastepaper does not always exactly match the output of paper products. During the 1981–82 period, some domestic paper manufacturers substituted wastepaper for woodpulp as a feedstock because of price differentials, even though overall paper production declined by about 4 percent. Woodpulp consumption declined about 7 percent during this period, while consumption of wastepaper products fell only 3 percent.[18]

Exports also affect the demand for, and output of, processed wastepaper. Many countries rely heavily on imported wastepaper as a basic feedstock for paper manufacturing because they do not have large domestic supplies of woodpulp or the prices of U.S. wastepaper may be competitive with native-produced woodpulp.[19] Since the 1960's, the importance of exports has grown dramatically. Exports accounted for less than 3 percent of total processed wastepaper in the 1960's, for about 10 percent of total production in the late 1970's, and for almost one-fourth of overall production by 1986. Exports to the Far East (mainly from West Coast processors) currently account for about two-third of total U.S. wastepaper exports.

Like scrap processing, wastepaper processing is highly regional, mainly because of transportation costs. Between 1977 and 1986, annual and long-term changes in output varied greatly among regions. During this period, consumption of processed wastepaper increased by almost two-thirds in Southern States—from 2.5 million tons to just over 4 million tons, and declined by about one-eighth in mid-Atlantic States—from 2.6 million tons to 2.3 million tons.[20]

Employment and hours

Between 1977 and 1987, the number of persons engaged in scrap and waste processing decreased slightly from 120,400 to 116,600, reflecting a decline in the number of self-employed and unpaid family members. The number of self-employed workers and unpaid family members fell from about 37,000 to 30,000, while the number of paid employees increased by about 3,000. As processing equipment and land grew more expensive, many small-scale scrap and waste dealers and processors left the industry.[21]

Average hours of all persons working in the scrap and waste materials industry remained fairly constant over the 1977–87 period at about 40 hours per week—similar to the average for all manufacturing combined. Average weekly hours of both employed and self-employed persons were about the same. These hours, however, obscure the seasonal pattern of processing. Because most scrap processing occurs out of doors, processing typically slows during winter months in Northeastern and North Central States: employees in these areas usually work fewer hours during the winter than during other seasons. In some cases, it is not unusual to find their average weekly hours exceeding 45 or 50 in the spring, summer, or fall.[22]

Weather also is important in wastepaper processing. While the weekly hours pattern in scrap processing has been somewhat attenuated in recent years because of year-round collection and recycling efforts, wastepaper collection, particularly in Northeastern and Midwestern States, traditionally declines during summer and winter months.[23]

Occupational structure

The occupational structure of the scrap and waste materials industry remained basically unchanged between 1977 and 1987, with the vast majority of paid employees operating various pieces of processing equipment and material movement vehicles or engaged in maintenance activities. The remainder of the work force consists of clerical workers and sales personnel, with salespersons accounting for about 10 percent of total paid employees.

Because of the variety of processing equipment in the industry, workers are trained to operate more than one type of machinery. In scrap processing establishments, especially, workers may be assigned various tasks depending on the level and type of processing being done. For example, baler operators are often trained to operate other pieces of processing equipment, such as shears or shredders. Material movement operators—forklift and crane operators and truckdrivers, for example—are also capable of operating more than one type of vehicle.

Industry structure

The scrap and waste materials industry consists of three types of establishments—scrap dealers, whose primary function is to collect and sort scrap metal for distribution to processors; scrap processors, who use power equipment to process scrap into marketable forms; and waste and secondary materials dealers and processors, who primarily collect and bundle various types of wastepaper. Between 1977 and 1987, the number of scrap dealer establishments increased from 1,741 to 1,864; scrap processors, from 2,065 to 3,893; and waste and secondary materials dealers and processors, from 3,655 to 4,007. Despite the relatively large number of establishments, there appears to be a fair amount of economic concentration in the industry. In 1976, for example, estimates show that the 100 largest wastepaper dealers accounted for about one-half of total wastepaper processed.[24] Likewise, the 50 largest scrap processors accounted for only 5 percent of all establishments, but for more than one-fourth of total industry value of shipments. It should be noted that because markets for scrap metal and wastepaper are highly localized, many metropolitan market areas are dominated by a small number of processors and dealers.

Although the number of scrap processing establishments increased slightly between 1977 and 1982, there was a significant shift in industry structure towards larger size establishments. In 1974, 439 small-size establishments capable of processing less than 6,000 tons of scrap per year accounted for one-third of all scrap processing establishments; by 1984, 352 small-size establishments accounted for only one-quarter of all establishments.[25] During the same period, the number of larger size establishments capable of processing 30,000 tons or more of scrap a year increased from 372 to 568.

Unlike scrap processors, the configuration of wastepaper establishments remained fairly constant during the 1977–87 period. Between 1977 and 1982, the number of establishments employing 14 or fewer employees increased by 16 percent (from 2,388 to 2,777), a percentage increase similar to that for establishments employing 20 workers or more. While establishments employing fewer than 14 workers account for about four-fifths of all wastepaper processing establishments, they account for only about one-third of wastepaper value of shipments and employment.

Processing techniques and technologies

Ferrous scrap is sorted and processed into more than 80 different grades using a variety of equipment. The basic equipment are shears, balers, shredders, turning crushers, briquetters, and motor block breakers; with shears, balers, and shredders accounting for the bulk of processed output. Shears are used to cut pieces of heavy scrap, such as structural steel beams, into uniform lengths. Alligator shears, introduced in the 1920's, use mechanical pressure, somewhat like a pair of scissors, to cut scrap. Guillotine shears, first introduced in the late 1950's, use hydraulic pressure to operate the cutting blades, and can process heavier grades of scrap than can alligator shears. Balers compress a variety of lighter weight scrap, such as flat rolled steel used in consumer goods, into high density bundles. Introduced in the early 1960's, shredders rip automobile hulks and used consumer and industrial products into small pieces, separating ferrous from nonferrous scrap and nonmetal materials, using air or water jets and magnets. In addition to processing equipment, scrap processors also use a wide variety of cranes, trucks, and loaders.[26]

The largest factor likely to affect wastepaper processing in the future is the growth of municipal recycling efforts.

Since the 1970's, the profile of processing equipment used by the industry has changed dramatically, with the emphasis shifting from sheared to shredded scrap. For example, in 1974, shredders were used to process 7.3 million tons of scrap, or about 14 percent of total processed scrap. In 1984, shredders processed 11.2 million tons of scrap, or 29 percent of total output. At the same time, the production of sheared scrap fell from 19 million tons to 13 million tons. This shift toward shredded scrap is reflected in the decrease in the number of shears

in operation over the 1974–84 period, from just under 3,000 to 1,400, while the number of shredders increased from 120 to 200.

Shredders are more expensive to operate than are shears, but their average output per employee hour is typically much higher.[27] For example, crew size for a guillotine shear is typically three to five employees and production averages about 15 tons per hour. Shredders, however, typically have five to seven crew members with an average production rate of 52 tons per hour.

Because of the variety of processing equipment in the industry, workers are trained to operate more than one type of machinery.

In addition to the shift toward shredded scrap since the mid-1970's, the industry has also been installing higher capacity processing machinery. In 1974, for example, guillotine shears with a capacity to process 25 tons or more of scrap per hour accounted for just 6 percent of all guillotine shears installed nationwide; by 1984, that proportion had doubled to 12 percent. Many of these newer generations of processing equipment also require less power to operate and have lower maintenance requirements than did previous generations.[28]

Since the late 1970's, other changes in manufacturing technologies and processes have also contributed to increased scrap processing productivity, such as the introduction of quicker methods of loading processed scrap on railroad gondolas, trucks, barges, and ships, and improvements in the movement of materials within processing facilities.

In recent years, a number of safety, environmental, and quality issues have affected scrap processing methods. Although shredders produce fewer emissions than did previous scraping techniques, such as incineration of auto hulks, they also increase the amount of hand processing operations required prior to machine processing. For example, autos must be stripped of potentially hazardous equipment before being shredded, and residual gasoline, grease, and airbag cylinders can cause explosions if they are not removed prior to processing. Scrap processors must also identify other potential contaminants and dangerous substances in incoming unprocessed scrap. Sophisticated monitoring devices must be used to detect radioactive scrap and scrap contaminated with PCB. Also, testing apparatus is used to determine the level of alloys present in ferrous scrap. Because the amount of unprocessed scrap made up of such alloyed steels has increased over the past decade, and because steel mills are demanding purer forms of processed scrap, processors are expending more efforts to test and analyze unprocessed scrap.[29]

Although wastepaper processors employ fewer types of processing and material movement equipment than do scrap processors, advances in automation and material movement techniques were made during the 1977–87 period. Since the mid-1970's, new types of paper balers—the chief piece of processing machinery—automatically bind bundles of compressed wastepaper with wire bands and are usually flush mounted into the floor of the processing facility, which allows for easier loading of loose wastepapers.[30]

Capital investments

Capital requirements are significantly higher for scrap processors than for wastepaper processors, mainly because of the cost of processing equipment. For instance, the typical cost of a wastepaper baler is currently about $100,000 to $250,000, while the cost of a moderate capacity shredder is between $2 million to $3 million.[31] The total current-dollar replacement value of capital equipment used in scrap processing increased from $1.8 billion in 1974 to $3.4 billion in 1984.[32] Since the late 1970's, the cost of scrap processing equipment has risen significantly—reflecting not only general price increases, but also growing complexity. For example, environmental concerns have prompted the installation of pollution control devices on existing and new processing machinery; the cost of these devices can amount to a significant proportion of capital equipment costs.[33] For instance, a pollution or effluent control device can add from 10 percent to 15 percent to the cost of processing equipment (primarily shredders and briquetters). While these control devices do not significantly increase the cost of processing a ton of scrap, the additional investment can significantly affect profit margins.

Outlook

Future changes in output per hour of all persons in the scrap and waste materials industry will hinge on developments in processing equipment and technologies and changes in the demand for, and supply of, processed scrap and waste materials.

Three major trends are evident in scrap processing equipment and manufacturing processes: continued advances in machine capacity, material handling methods, and pollution control technologies; increasing emphasis on scrap quality; and changes in demand.

Between 1985 and 1990, scrap processors plan to expand processing capacity by about 5 million tons.[34] In addition, improved materials handling, workflow, and operations could significantly increase output per hour of all persons by as much as 5 percent to 10 percent.

Partially offsetting these improvements are such factors as increased concern over scrap quality and continuing changes in steel manufacturing technologies and processes. As the demand for high quality scrap increases, scrap processors will have to expend more employee hours to analyze and sort incoming unprocessed scrap as well as identify hazardous materials. In addition, future changes in steelmaking technologies and processes, such as more efficient ways to manufacture steel from directly reduced iron and the shift to just-in-time deliveries of processed scrap, could dampen potential gains in output per hour. In 1984, it was estimated that an uninterrupted, continuous market demand for scrap could have prompted the production of an additional 20–25 million tons of scrap through better and higher utilization of existing processing machinery.[35]

The largest factor likely to affect wastepaper processing in the future is the growth of municipal recycling efforts. While a few municipalities sell wastepaper directly to paper mills, bypassing traditional wastepaper processors, large-scale mandatory recycling would increase the supply of, but not necessarily the demand for, wastepaper. Wastepaper processors have traditionally paid for unprocessed wastepaper; however, in localities where supply greatly outpaces demand, processors are paid just to receive and warehouse unprocessed wastepaper—increasing their inventories of unprocessed wastepaper and the number of employee hours required to maintain them.[36]

Research and development also will play an important role in future scrap and waste processing. For example, an ongoing cooperative venture between the Bureau of Mines and the Institute of Scrap Recycling Industries is designed to prod the development of more efficient processing methods and enhance the exchange of information relating to scrap metal and waste materials.[37] □

Footnotes

[1] The scrap and waste materials industry is designated as SIC 5093 by the 1987 *Standard Industrial Classification Manual* of the U.S. Office of Management and Budget. The industry consists of establishments primarily engaged in assembling, breaking up, sorting, and wholesale distribution of scrap and waste materials. It should be noted that although the industry is classified as a wholesale industry, each State classifies it as a manufacturing industry for tax purposes.

In November 1976, the Institute of Steel and Iron Scrap (precursor to the current Institute of Scrap Recycling Industries) petitioned an interagency committee of the Federal Government, the Technical Committee on Industrial Classification, to change the industrial classification of scrap processors from wholesaling to manufacturing, citing advantages in zoning, taxation, and inventory accounting procedures. The request was denied on the grounds that it would be too difficult to separate processors from collectors, sorters, agents, and brokers. Agents and brokers who do not physically take possession of processed scrap and waste, but act as middlemen between suppliers and consumers, accounted for less than 5 percent of all establishments in the industry in 1982, less than 8 percent of total industry value of shipments, and about 2 percent of all workers. See K. W. Palmer, "Iron and Steel Scrap," *Bureau of Mines Minerals Yearbook, 1977*, p. 530; and industry sources.

Average annual rates of change are based on the linear least squares of the logarithms of the index numbers. Extensions of the indexes will appear in the Bureau of Labor Statistics annual bulletin, *Productivity Measures for Selected Industries*.

[2] Franklin D. Cooper, "Iron and Steel Scrap," *Bureau of Mines Minerals Yearbook, 1983*, pp. 502–03.

[3] Because of the higher intrinsic value of nonferrous scrap, the proportion of industry value of shipments accounted for by nonferrous scrap is higher than these physical tonnage proportions would indicate. Scrap copper, for example, is currently worth about $750 per ton, compared with about $25 per ton for ferrous scrap steel. This large difference does not reflect differences in value added by the scrap processing industry—in fact, less processing is usually performed on nonferrous than on ferrous scrap. Rather, it reflects the relative scarcity or abundance of different metals.

[4] Overall, 30 percent to 40 percent of obsolete ferrous scrap is obtained from discarded automobiles. The second largest source is structural iron and steel coming from the demolition of domestic or industrial structures. Scrapping of obsolete ships usually occurs in overseas scrap yards because of the relatively labor-intensive nature of the work, which involves extensive use of hand-operated cutting torches, and environmental problems associated with asbestos. See James W. Sawyer, Jr., *Automotive Scrap Recycling: Processes, Prices, and Prospects* (Washington, Resources for the Future, 1974), pp. 4–14; and Franklin D. Cooper, "Iron and Steel Scrap," *Bureau of Mines Minerals Yearbook, 1984*, p. 530.

[5] The supply and demand functions for obsolete scrap are very complex. Supply and demand depend on the relative costs of various inputs used in steel manufacturing, and upon vagaries of local supply and demand conditions. For example, an increase in the demand for a particular type of obsolete scrap in a locality will cause prices and supplies to rise until local supplies are exhausted or the limit of local scrap processing capacity is reached. At that point, the supply function shifts dramatically from being highly elastic to totally inelastic—regardless of the price offered, local supply does not change. See Sawyer, *Automotive Scrap Recycling*, pp. 103–10.

[6] From 1977 to 1987, the proportion of total raw steel production accounted for by electric arc furnaces increased from just under one-fifth to one-third. This shift to electric arc furnaces marks the second major shift in steel manufacturing technologies since the 1950's. The previous shift was the supplanting of open hearth furnaces with basic oxygen furnaces. In 1959, basic oxygen furnaces accounted for 8 percent of total steel production; by 1969, the proportion was 43 percent. Both open hearth and basic oxygen furnaces

can use 30 percent to 40 percent scrap in their charges, compared with close to 100-percent scrap charges used in electric arc furnaces. See Josapht Plater-Zyberk, Jr., "The Economics of Ferrous Scrap Recycling" (Ph. D. diss., Drexel University, June 1972), pp. 62–69; and Gregory L. Miles, "U.S. Minimills Launch a Full-Scale Attack," *Business Week*, June 13, 1988, pp. 100–02.

[7] Current-dollar value of industry shipments increased from $10,350,085,000 in 1977 to $12,260,267,000 in 1982. While, in general, these figures reflect the value of industry output, they do not reflect the value of the industry's final (net) output because they include the value of shipments from dealers to processors, as well as the value of final processed scrap and waste shipped by the industry to end users.

[8] Raymond E. Brown, "Iron and Steel Scrap," *Bureau of Mines Minerals Yearbook, 1987*, p. 3.

[9] Since 1956, the supply of low-grade unprocessed scrap has grown steadily. In 1987, for example, the Institute of Scrap Recycling Industries estimated that there were more than 800 million tons of unprocessed ferrous scrap residing in involuntary inventories due to lack of markets.

[10] *The Processing Capacity of the Ferrous Scrap Industry*, Research Report (Columbus, OH, Battelle Columbus Laboratories, Oct. 7, 1985, p. 18, and Aug. 10, 1976, p. 19).

[11] Raymond E. Brown, "Iron and Steel Scrap," *Bureau of Mines Minerals Yearbook, 1986*, p. 3.

[12] Transportation fees are usually calculated in terms of cents-per-mile, with railroad and over-the-road cartage being more expensive than barge or ship transportation. A scrap processor would typically incur losses on processed scrap if it were shipped more than 100–200 miles. See Sawyer, *Automotive Scrap Recycling*, pp. 39–40.

[13] Although increasing from 6 million tons to 11 million tons between 1977 and 1987, annual exports of obsolete ferrous scrap have traditionally fluctuated between 5 million tons and 11 million tons since the 1930's. From the late 19th century to the present, the United States has been an exporter of scrap, and today accounts for about one-third of total worldwide ferrous scrap export trade. Other major scrap exporting nations are France, Federal Republic of Germany, United Kingdom, and the U.S.S.R. United States imports of ferrous scrap currently amount to about 2 percent of total annual domestic scrap consumption. See Edwin C Barringer, *The Story of Scrap* (Washington, Institute of Scrap Iron and Steel, 1954), pp. 60–67; and *Bureau of Mines Minerals Yearbook*, various issues.

[14] "Recycling Waste Paper," *Phoenix Quarterly*, vol. 19, no. 3, Fall 1987, p. 10.

[15] Thomas Plaut and Gene Steiker, *Characteristics of Wastepaper Markets and Trends in Scrap Paper Recycling, Prices, Demand and Availability: A National and Regional Overview*, Discussion Paper Series No. 103 (Regional Science Research Institute, April 1978), pp. 10–11.

[16] American Paper Institute, *1986 Annual Statistical Summary Waste Paper Usage;* and industry sources.

[17] The degree of wastepaper recycling has varied dramatically over the years. During World War II, for example, an estimated 35 percent of all paper was recycled, a figure not attained since, even though the recycling rate increased during the 1970's to about 25 percent. See "Recycling Waste Paper," p. 9.

[18] While the consumption of wastepaper varies with trends in overall paper production, the supply of wastepaper available for processing and recycling remained fairly constant over the 1977–87 period. Given this rather steady supply but variable demand, the demand and supply of unprocessed wastepaper is very price inelastic—as the demand for processed wastepaper increases, the price will increase a great deal while the quantity available for processing will increase relatively little; conversely, if demand falls, the price will decline sharply while the available supply of unprocessed wastepaper will decline relatively little. During periods of declining or low prices, wastepaper processors significantly reduce their output of processed wastepaper and purchases of unprocessed wastepaper. See Thomas Plaut, *An Econometric Analysis of Regional Wastepaper Markets*, Discussion Paper Series No. 104 (Regional Science Research Institute, June 1978).

[19] "Recycling Waste Paper," p. 10.

[20] Southern States include Alabama, Delaware, Florida, Georgia, Kentucky, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. Mid-Atlantic States include New Jersey, New York, and Pennsylvania.

[21] Franklin D. Cooper, "Iron and Steel Scrap," *Bureau of Mines Minerals Yearbook, 1983*, p. 501.

[22] *The Processing Capacity of the Ferrous Scrap Industry*, 1976, p. 19.

[23] Plaut and Steiker, *Characteristics of Wastepaper Markets*, pp. 22–24; and industry sources.

[24] Plaut and Steiker, *Characteristics of Wastepaper Markets*, p. 14.

[25] *The Processing Capacity of the Ferrous Scrap Industry*, 1985, p. 8.

[26] In 1984, the industry possessed more than 2,700 scrap processing machines and about 33,000 pieces of transportation, materials handling, and other miscellaneous equipment. See *The Processing Capacity of the Ferrous Scrap Industry*, 1985, p. 13.

[27] *The Processing Capacity of the Ferrous Scrap Industry*, 1976. Daily production rates of various pieces of processing equipment largely depend on the type of scrap being processed, operating conditions, and machine capacity. Shredders, for example, can process between 15 tons to 100 tons of scrap per hour, while guillotine shears producing pieces 3 feet and under can consistently achieve greater efficiencies than shears producing 2-foot pieces.

[28] Franklin D. Cooper, "Iron and Steel Scrap," 1984, p. 575.

[29] *Ibid*, pp. 529–30.

[30] Industry sources.

[31] Even in 1974, prices of scrap processing machinery were relatively high, with alligator shears costing between $8,000 to $35,000; guillotine shears between $60,000 and $1,600,000; and shredders, $400,000 to $4,000,000. See *The Processing Capacity of the Ferrous Scrap Industry*, 1976, p. 18.

[32] *The Processing Capacity of the Ferrous Scrap Industry*, 1976, p. 18.

[33] See Sawyer, *Automotive Scrap Recycling*, pp. 121–23.

[34] *The Processing Capacity of the Ferrous Scrap Industry*, 1985, pp. 18–19.

[35] *Ibid.*, p. 19.

[36] In early 1989, just such a situation arose in some Northeastern metropolitan areas, where a glut of unprocessed papers overturned the traditional market role of processors. Both reflecting and compounding the problem was a simultaneous decline in prices for exported wastepaper. See Jerry Johnson, "Who Wants Yesterday's Papers?" *City Paper*, June 9–15, 1989, pp. 16–21.

Because the nature of reclaimed municipal ferrous scrap,

mainly tin-plated steel cans, limits its use as a raw material for steel production, scrap processors will not face this problem in the foreseeable future. See Raymond E. Brown, "Iron and Steel Scrap," p. 5.

[37] Franklin D. Cooper, "Iron and Steel Scrap," 1984, p. 586.

APPENDIX: Measurement techniques and limitations

Indexes of output per hour of all persons measure changes in the relationship between the output of an industry and hours expended on that output. An index of output per all person hours is derived by dividing an index of output by an index of industry all person hours.

The preferred output index for an industry is obtained using data on quantities of the various goods produced by the industry, each weighted (multiplied) by the hours required to produce one unit of each good in some specified base period. Thus, those goods which require more labor time to produce are given more importance in the index. This technique was used to develop the output index for the scrap and waste processing industry. The output measure is based on physical quantities of various groups of industry products weighted together using labor weights.

The indexes of output per hour relate output to one input—labor time. The indexes do not measure the specific contributions of labor, capital, or any other single factor. Rather, they reflect the joint effect of factors such 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.

The complete data series for the industry, including indexes of output per hour of all persons, hours of all persons, all persons, and matrixes showing year-to-year least squares percent changes in the indexes are available from the Bureau.