CHROMIUM USE BY MARKET IN THE UNITED STATES

J.F. Papp[1]

[1]U.S. Geological Survey, 989 National Center, Reston, Virginia, 20192, United States of America.
E-mail: jpapp@usgs.gov

ABSTRACT

In the United States, chromium has been consumed in three major markets: chemical, metallurgical, and refractory. The predominant end use for chromium in the United States is in the metallurgical market as an alloying element in the production of stainless steel. In addition to being a major stainless steel-producing country, the United States is a major world producer of chromium-containing chemicals and has used substantial amounts of chromite ore for refractory applications. Chromium use is not easily further subdivided within the chemical and refractory industries because there is insufficient publicly available information to do so; however, chromium use can be subdivided among metallurgical industry uses based on the American Iron and Steel Institute (AISI) reported shipments of stainless steel by market classification (agricultural, aircraft, automotive, etc.). It is the goal of this study to determine the distribution of U.S. chromium apparent consumption among major markets in the United States. The distribution is expressed in the form of dimensionless fractions that are computed based on documented chromium consumption by major market. The distribution of chromium among markets within the metallurgical market is computed in a similar manner.

Distribution factors are first computed for the major markets, then for markets that are subdivisions of the metallurgical market. The distribution of chromium among major markets has changed substantially over the time period of analysis. The fraction of chromium consumed by the metallurgical market has increased while that of the chemical and refractory markets has declined. Within the metallurgical market, the service industry market accounts for the greatest fraction of chromium consumption followed by transportation. Electrical, machinery, and fabricated products markets account for a substantial share of the metallurgical chromium consumption.

1. INTRODUCTION

In the United States, chromium has been and is consumed by the chemical, metallurgical, and refractory industries. The amount of chromium consumed by end use within the refractory industry is small. Chemical industry analysts have sporadically estimated the amount of chromium consumed by end use within the chemical industry. Metallurgical industry chromium consumption can be further subdivided by market based on reported shipments of stainless steel by market classification.

The major primary sources of chromium supply are in the form of imported and domestically mined chromite ore, and imported chromium ferroalloys and metal. Domestically mined chromite ore was last reported in 1961. The distribution of chromium among major markets can be estimated based on chromite ore consumption reported by the those markets. The objective is to estimate the distribution of U.S. chromium apparent consumption among end uses. Estimating the annual distribution of U.S. chromium consumption and applying that distribution to U.S. chromium apparent consumption will do this.

2. APPARENT CONSUMPTION

Apparent consumption is defined as production plus net imports minus stock change. It is applied to a commodity within a national boundary to estimate that nation's demand for that commodity. Typically, it is computed on an annual basis. Production includes both primary, i.e., from mining, and secondary, i.e., from recycling. Net imports are imports minus exports. Stock change is year-end stocks minus year-beginning stocks. Stocks may include those of producer and consumer industry, traders, or government.

As defined, apparent consumption is a material balance at the national scale that indicates national demand for the commodity. Those materials that are important and about which we have information should be included in the material balance. “Important” here indicates that the material accounts for a significant fraction of chromium trade. As one moves through the chain of materials from ore production through intermediate materials and consumer and industrial products, the amount of chromium contained in a material becomes more uncertain. For example, chromite ore, chromium ferroalloys, and metal alloys are the first three materials in chromium use. Chromite ore and chromium ferroalloy import data collected by the Federal Government are reported as the gross and contained weight of these materials. In the Harmonized Tariff System of the United States, metal alloys are classified into broad groupings for the purpose of trade, and their constituent contents are not reported.

For production, chromite ore is the material measured for primary production; stainless steel scrap is the material measured for secondary production. The materials included in net imports are, to a large degree, shaped by the trade categories of the harmonized tariff system. The chromium contained in chromite ore and chromium ferroalloy trade is more certain than that in metal alloys and products that incorporate those alloys such as mill products, machinery, vehicles, or the myriad of other products that contain metal alloys. Chromite ore, chromium ferroalloys and metal, and selected chromium chemicals (those for which chromium content can be estimated) are the materials included in net trade.

Similar considerations apply to stocks resulting in the inclusion of chromite ore, chromium ferroalloys and metal among the materials accounted for in stocks. For chromium stocks, only consumer industry stock data are available for chromium ferroalloys and metal, and government stocks for chromite ore and chromium ferroalloys and metal. In past years, consumer stocks of chromite ore and producer stocks of chromium ferroalloys and metal have contributed to the stocks portion of apparent consumption. Trader stocks have never been used in chromium apparent consumption.

3. MARKETS

The markets among which chromium consumption is to be distributed are indicated by those industries that appear in the discussion about apparent consumption: the chemical, metallurgical, and refractory industries. Virtually all other industrial uses of chromium start with a product of one of these industries. Since these are industries that consume chromite ore, the first use of chromium after it is mined, they are the major subdivisions of the market place and are called the major markets. The largest of these is the metallurgical market, which can be further subdivided. Together, the chemical and refractory major markets and the subdivisions of the metallurgical market are the markets across which chromium will be distributed.

The distribution of chromium among markets will be expressed as a dimensionless fraction computed annually based on reported consumption and trade information. The distribution will be computed in two parts: first for the major markets (chemical, metallurgical, and refractory), then for the markets that are a subset of the metallurgical major market. The use of all chromium materials across the many paths taken from mining to end use is not known and can not be tracked; however, something is known about chromium material flow at certain points in the use cycle. In particular, production and trade of chromite ore and many chromium-containing materials are known. Something is also known about the amount of chromium consumed by the major consuming industries (chemical, metallurgical, and refractory), and something is known about the amount of shipments of the major chromium-containing alloys (stainless steel shipments). The assumption is made in this study that what is known represents all of apparent consumption, and it is used to subdivide chromium consumption by industry.

3.1 Major Market Distribution

The major markets are the chemical, metallurgical, and refractory markets. The distribution of chromium among these major markets can be computed from their reported consumption and trade data.

The source of chromium in the chemical and refractory industries is chromite ore; however, the source of chromium in the metallurgical industry includes chromium ferroalloys and metal and stainless steel scrap in addition to chromite ore. Therefore, the distribution of chromium among major markets is based on reported chromite ore consumption by the chemical, metallurgical, and refractory industries plus net imports of chromium ferroalloys and metal and consumption of stainless steel scrap.

Since 1940, the U.S. Geological Survey and the U.S. Bureau of Mines have collected and published chromite ore consumption data from these chromite ore consumer industries. From 1986 through 1994, reported chromite ore consumption for the chemical and metallurgical industries was combined to protect company proprietary information; however, chromite ore consumption for the refractory industry continued to be reported through 1994. From 1995 through 1998, chromite ore consumption for all three major markets was combined to protect company proprietary information. Metallurgical industry chromite ore consumption ended in 1998 when ferrochromium production from chromite ore stopped. Therefore, starting in 1999, only chromium ferroalloy and metal trade contribute to metallurgical industry share. To continue to protect company proprietary data, the distribution of chromium among these major markets is based on trend values. Using trend values has the added benefit of eliminating sometimes-large short-term fluctuations that visually distract from graphical representations of the consumption.

For the distribution of chromium apparent consumption among major markets, annual reported chromite ore consumption is assumed to represent all of chemical and refractory industry consumption and part of metallurgical industry consumption. Domestic stainless steel scrap receipts and net trade of chromium ferroalloys and metal account for the remainder of metallurgical industry consumption. The amount of chromium reported consumed by these major markets divided by their sum, is the distribution of chromium consumption by market represented as a dimensionless fraction that can be multiplied by chromium apparent consumption to get a value for annual chromium consumption for that sector measured in mass of chromium consumed. A linear trend line was fitted to the results of this computation. Figure 1 shows the trend of distribution of U.S. chromium apparent consumption among major markets computed in this manner and the trend among major markets (chemical, metallurgical, and refractory) based on data from 1940 through 2001. The figure shows that while the metallurgical market share have increased substantially, the chemical industry market share has declined slightly, and the refractory industry market share has declined into obscurity. The trend line shows that in 2000, the metallurgical industry accounted for about 90% of chromium apparent consumption while the chemical industry accounted for about 10% of chromium apparent consumption. In the 1991 to 1994 time period, the refractory market accounted for between 1% and 2% of chromium apparent consumption and the amount was declining.

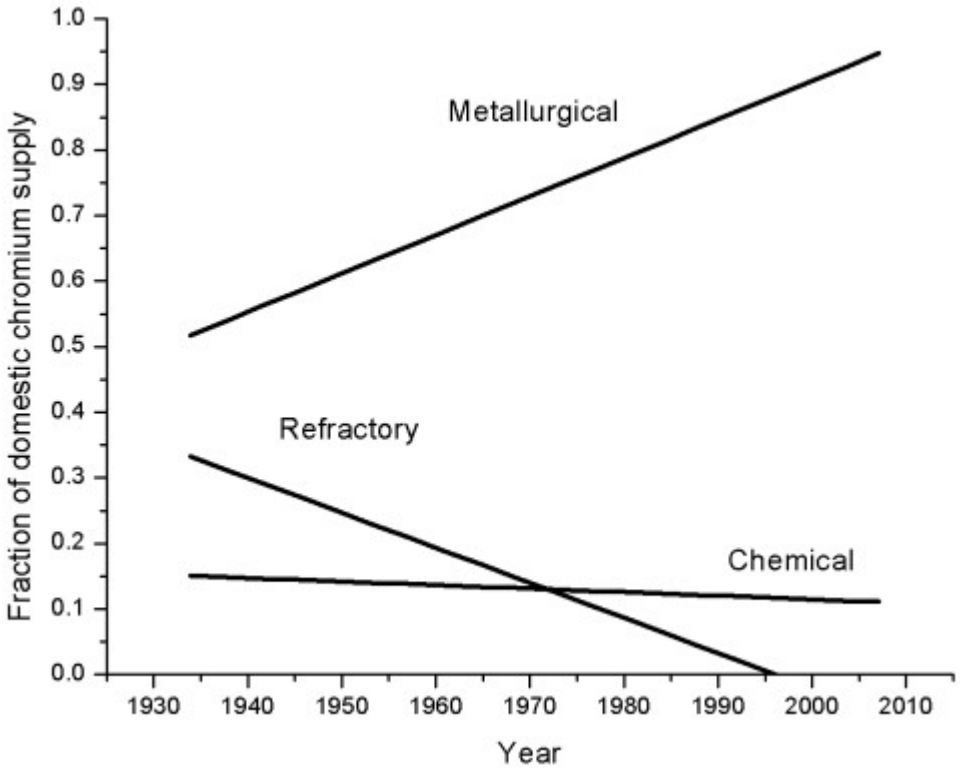

Figure 1. Trend of distribution of U.S. chromium apparent consumption among major markets (chemical, metallurgical, and refractory) based on data from 1940 through 2001.

Another way to view this distribution after 1995 when the refractory industry accounted for only a small portion of U.S. chromium apparent consumption is to assume that the chromite ore supply has gone to the chemical industry and that the chromium ferroalloy and metal supply and stainless steel scrap receipts have gone to the metallurgical industry. With this assumption and using net imports to estimate supply, from 1995 through 2001, the distribution of chromium between the chemical and metallurgical markets averages 86% metallurgical-14% chemical. Yet another way to estimate supply is to include both net imports and stock changes. The National Defense Stockpile made substantial sales over this time period. Estimating supply in this way, from 1995 through 2001, the distribution of chromium between the chemical and metallurgical markets averages 79% metallurgical-21% chemical. Clearly, the metallurgical industry dominates U.S. demand; however, by how much is somewhat uncertain because of ambiguity in the data.

3.2 Metallurgical Market Distribution

Chromium is consumed in the metallurgical industry as an alloying element to produce a variety of alloys including aluminum-, cobalt-, copper-, iron-, nickel-, and titanium-base alloys. Most chromium is alloyed with iron to make steel, and the remainder is used to make nonferrous alloys. On average from 1981 through 2001, the steel industry accounted for more than 91% of reported chromium consumption [1]. By far, the steel grade that accounted for the most chromium is stainless steel. On average from 1981 through 2001, the stainless steel industry accounted for more than 76% of reported chromium consumption and 83% of reported chromium consumption for steel production [1]. The American Iron and Steel Institute (AISI) reports stainless steel shipments by market classification. The distribution of those shipments will be used to estimate the distribution of chromium consumed by metallurgical market. The stainless steel shipment quantities divided by their sum are the distribution of chromium among metallurgical markets. Those ratios multiplied by the distribution of U.S. chromium apparent consumption to the metallurgical major market are the distribution of U.S. chromium apparent consumption by metallurgical market. Measuring consumption in dimensionless fractions permits comparison of distribution of stainless steel shipments with that of steel, all grades, shipments and comparison of their trends.

The distribution of chromium among market classifications is assumed to be the same as that of stainless steel shipments. This distribution is computed based on AISI [2] reported stainless steel shipments from 1989 through 2001 and is compared with that for steel shipments [3] from 1964 through 2001.

The market classifications used by AISI to report steel and stainless steel shipments are listed in table 1 along with the markets with which they are associated. The markets are drawn from the North American Industry Classification System (NAICS) codes at the three-digit level. With one exception, all of the market classifications used by AISI may be associated with a NAICS industry classification. The exports classification cannot be associated with a specific market. Since the exports market classification cannot be assigned a NAICS industry classification, the distribution was computed excluding exports. The remainder of the AISI market classifications were associated with the manufacturing sector, NAICS 31-33, and the wholesale trade, NAICS 42. For the purpose of this report, manufacturing is the chemical, mechanical, or physical transformation of metals into new products. Wholesale trade is the sale or arranging for purchase or sale of metals for resale; in particular, metal service centers engage in this type of trade.

Analysts designed NAICS to group business establishments into industries based on the activities in which they primarily engaged for the purpose of collecting and reporting statistical information [4]. It was not meant to categorize manufactured products such as those of the metals industry discussed in this report; however, the system is well known and organizes the economy into clearly recognizable and commonly understood parts for the purpose of statistical analysis, so it was used here to categorize steel and stainless steel shipment information.

Table 2 shows the results of this computation. In 2000, chromium is distributed among metallurgical market, in decreasing market share, as 0.61 to the service industry market, 0.27 to the transportation market, 0.09 to the machinery market, 0.03 to the fabricated products market, and 0.01 to the electrical market. The service industry accounts for the largest market share. Consecutively smaller shares differ by a factor of 2 or greater.

Table 1. AISI market classifications and markets.

Major market name	Market name	NAICS market Code[1]		AISI[2] market classification
Chemical	Chemical	325	--	None
Refractory	Refractory	327	--	None
Metallurgical	of which:			
	Service industry (Wholesale trade, durable goods; Metal service centers).	421	3311, 3312	Converters and processors
			42151	Service centers or distributors
	Fabricated products (Fabricated metal product manufacturing).	332	332111	Forgings
			3325	Industrial fasteners
			3322	Appliances, utensils, etc.
			3324	Containers, packaging, and shipping
			332992-5	Ordnance and military
	Machinery (Machinery manufacturing).	333	33312	Construction
			--	Contractor products
			333132	Oil and gas
			333131	Mining, quarrying, lumbering
			33311	Agriculture
			333	Machinery, industrial equipment, tools
			--	Other domestic and commercial equipment.
	Electrical (Computer and electronic products (334); Electrical equipment, appliances, and component manufacturing (335)).	334-5	3336	Electrical equipment
	Transportation (Transportation equipment manufacturing).	336	3361	Automotive
			3365	Rail transportation
			3366	Shipbuilding and marine
			3364	Aircraft and aerospace
	--	--	--	Export

[1]NAICS North American Industry Classification System.
[2]AISI American Iron and Steel Institute.

Table 2. Chromium distribution among major markets, metallurgical markets, and markets for the year 2000.

Major market	Distribution	Metallurgical market	Distribution	Market[1]	Composite distribution
Chemical	0.10			Chemical	0.10
Metallurgical	0.90				
		Service industry	0.61	Service industry	0.55
		Fabricated products	0.03	Fabricated products	0.03
		Machinery	0.09	Machinery	0.08
		Electrical	0.01	Electrical	0.01
		Transportation	0.27	Transportation	0.24
Refractory	< 0.01			Refractory	< 0.01
Total	1.00		1.00		1.00

Data may not add to total shown owing to independent rounding.
[1] Market is the smallest subdivision of industry for the purpose of analysis in this report.

Figure 2 shows the trend of chromium distribution among metallurgical markets based on data from 1989 through 2001. The transportation market share of the metallurgical major market is increasing while those of the other markets are declining.

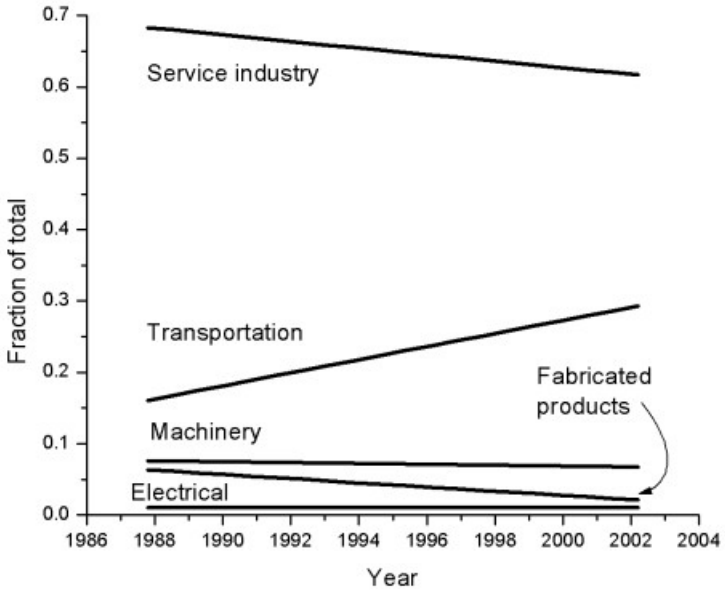

Figure 2. Trend of distribution of stainless steel shipments among metallurgical markets (service industry, fabricated products, machinery, electrical, and transportation) based on data from 1989 through 2001.

If the distribution of stainless steel among markets and the trends thereof are similar to those of steel, all grades, the steel, all grades, data could be used as a surrogate for stainless steel shipment data to estimated chromium distribution between 1964 and 1989. Figure 3 shows the trend of distribution of all grades ("all grades" means carbon plus alloy plus stainless steel.) of U.S. steel shipments among metallurgical markets based on data from 1964 through 2001. For all grades of steel over the 1964 through 2001 time period, the service industry market is increasing while those of the other markets are declining. The trend is different when analysed over the 1989 through 2001-time period. For all grades of steel over the 1989 through 2001 time period, the service industry, machinery, and transportation markets are increasing while those of the other markets (electrical and fabricated products) are declining. Inspection of figures 2 and 3 show that the distribution of stainless steel among market sectors and the trends thereof differ from those of steel, all grades.

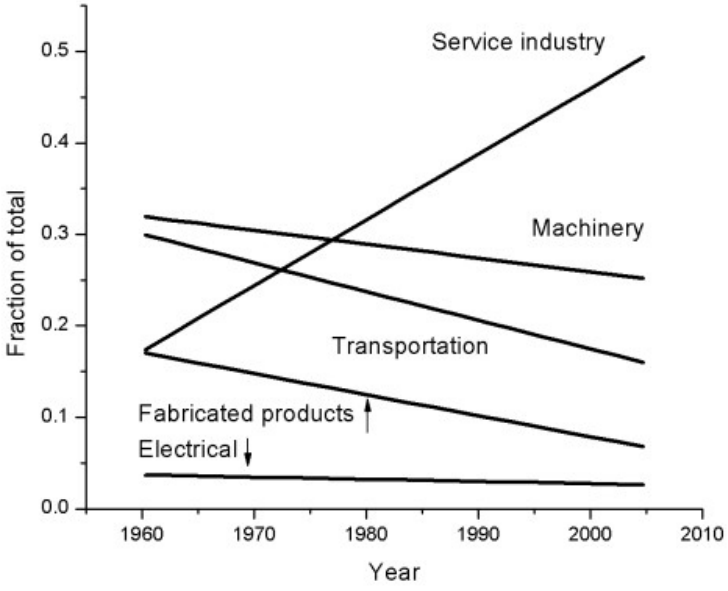

Figure 3. Trend of distribution of all grades of U.S. steel shipments among metallurgical markets (service industry, fabricated products, machinery, electrical, and transportation) based on data from 1964 through 2001.

4. DISTRIBUTION RESULTS

Table 2 shows the estimated distribution of U.S. chromium apparent consumption in 2000 by market. The distribution by market, in decreasing order of market share, is 0.55 to service industry, 0.24 to transportation, 0.10 to chemical, 0.08 to machinery, 0.03 to fabricated products, and 0.01 to electrical. Figure 4 shows the trend of distribution of chromium among markets (chemical, electrical and fabricated products, machinery, refractory, service industry, and transportation) based on data from 1940 through 2001.

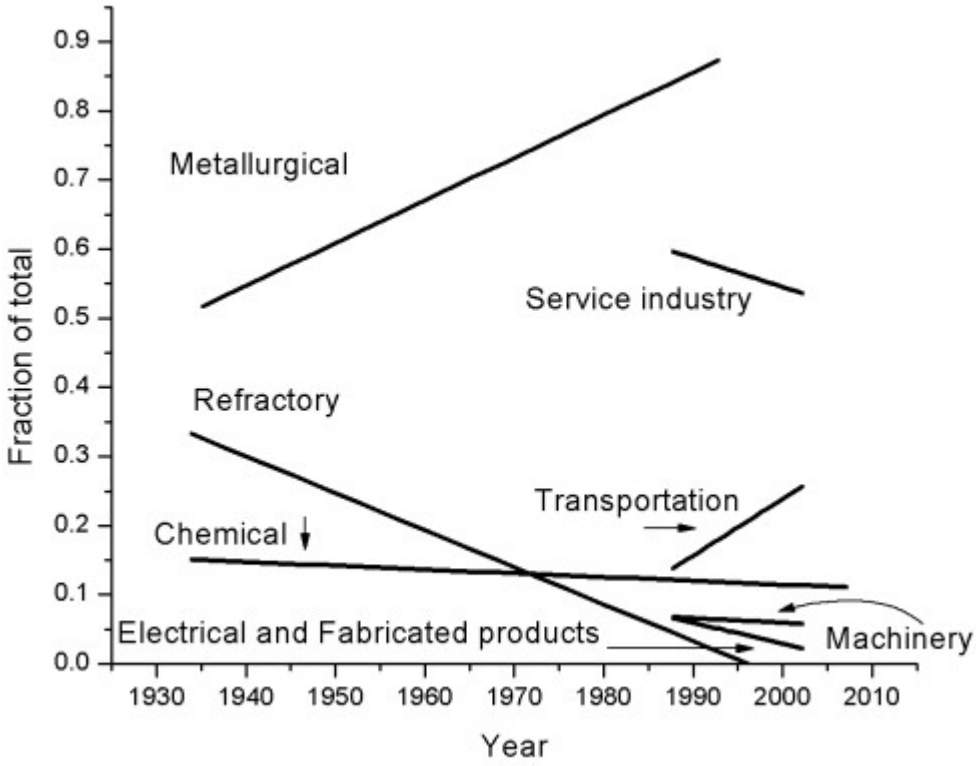

Figure 4. Trend of distribution of chromium among markets (chemical, electrical and fabricated products, machinery, refractory, service industry, and transportation) based on data from 1989 through 2001.

Stainless steel shipments by market form three groups by magnitude of fraction of shipments: high, medium, and low. The high group comprises the service industry market; the medium group, the transportation market; and the low group, the electronics, fabricated products, and machinery markets. Over the 1989 through 2001 time period, the service industry market is the most important market representing between 0.6 and 0.7 of stainless steel shipments. The transportation market is the second most important market representing 0.15 to 0.3 of stainless steel shipments. Electrical, fabricated products, and machinery markets each represent between 0.01 and 0.1 of stainless steel shipments.

The importance of the service industry market appears to be declining. The trend appears to be a reduction in the fraction of shipments from stainless steel producers to the service industry market. The trend of fraction of shipments to the electrical, fabricated products, and machinery markets is also declining with that of machinery showing the least decline. Only the transportation market shows a trend of increasing fraction of shipments. Perhaps this trend shows that the transportation industry is increasing its use of stainless steel to meet its needs – lower weight to improve fuel efficiency and longer-lasting, lower-maintenance materials to improve life-cycle cost – and that the transportation industry is doing it with the direct involvement of stainless steel producers.

The data for steel (all grades) shipments cover a longer time period than that for stainless steel. For the purpose of comparing distribution of shipments and shipment trends, steel (all grades) shipments were analyzed over the same time period as that for stainless steel.

The order of magnitude of the fraction of stainless steel shipments to service industry market has been between 0.6 and 0.7 compared to about 0.425 for steel (all grades). This indicates that stainless steel producers are more dependent than the steel industry in general on down stream processors and service centers to move their product into the consumers' hands. While shipments of stainless steel to the service industry market has been declining, that of steel (all grades) has been increasing. The fraction of stainless steel shipments to the fabricated products market has ranged from 0.07 to 0.11 compared to 0.02 to 0.06 for steel (all grades). The rate of decline is similar. The fraction of stainless steel shipments to the machinery market was between 0.1 and 0.5 compared to less than 0.25 to greater than 0.30 for steel (all grades). The trend of stainless steel shipments to the machinery market is decreasing while that of steel (all grades) is increasing. The fraction of stainless steel shipments to the electrical market ranged from under 0.005 to 0.015 while that of steel (all grades) ranged from above 0.02 to below 0.035. For both cases the trend was declining, but substantially faster for steel (all grades). The fraction of stainless steel shipments to the transportation market ranged form 0.15 to 0.27 while that of steel (all grades) ranged from 0.15 to 0.20. In both cases, the trend was increasing; however, the rate of increase was much faster for stainless steel shipments.

5. CONCLUSION

Since 1940, the metallurgical market moved from accounting for one-half to accounting for 80 percent of U.S. chromium apparent consumption. The chemical market accounts for slightly less of chromium apparent consumption today than it did in 1940. The refractory market, which accounted for over one-third of chromium apparent consumption in 1940, accounted for a negligible amount of chromium apparent consumption in 2000.

The analysis and comparison of stainless steel shipments with steel shipments suggests the following.

- The service industry market accounts for the greatest share of stainless steel shipments (over twice that of the market accounting for the second largest share and more than all of the other markets combined); however, its share is decreasing.
- The transportation market accounts for the about one-half that of the service industry; however, twice that of the third place market and its share is increasing.
- The remaining three markets, the electrical, fabricated products, and machinery markets, account for even smaller shares of stainless steel shipments.
- The transportation market appears to be taking market share away from the service industry market. Fractions of shipments and shipment trends in the stainless steel market are not similar to those of the steel (all grades) market.

Tracking stainless steel use as an indicator of chromium use by markets characterized by 3-digit NAICS codes is sufficient to characterize the stainless steel industry; however, it is not completely satisfying for the following reason. A large portion of stainless steel shipments goes to the service industry market from where it is distributed to other sectors. Upon distribution, that large share could change share attributed to the various manufacturing market sectors. For manufacturing markets, such as transportation, the stainless steel shipments represent a feed material that will be converted to use in that sector. For the service industry market, stainless steel shipments represent a feed material that will likely eventually be used in one of the manufacturing markets.

The service industry market accounts for a greater fraction of stainless steel shipments than steel (all grades) shipments. This suggests that there is greater vertical integration in the steel (all grades) industry than there is in the stainless steel industry.

The conclusions stated here are based on the data presented. Clearly, the large fraction of metal shipped to the service industry is processed and ends up mostly in the manufacturing markets specifically identified here or in some other markets. Allocation of that material among these markets could change their relative importance; however, there is no publicly available information about shipments from steel service centers and distributors, the major constituents of the service industry, upon which to base further analysis. Even if there were shipments information from the service industries market, identifying end use can be ambiguous.

Consider the following example. Steel is shipped from the producer to the service industry from where it is sold to the electrical industry to make motors. That steel went from the service industry market to the electrical market. The motor is installed in a truck. The steel is now being used in the transportation industry. The truck is used to haul ore at a mine. The steel is now used in the mining and quarrying industry.

6. REFERENCES

[1] Papp, John F., "Chromium" chapter *in* Minerals Yearbook, U.S. Geological Survey from 1995 through 2001 editions and U.S. Bureau of Mines from 1981 through 1994 editions.)

[2] American Iron and Steel Institute, "Stainless steel shipments by market classification", American Iron and Steel Institute publication AIS-16S, 1989 through 2001.

[3] American Iron and Steel Institute, "Annual Statistical Report", Steel shipments by market classification table, 1964 through 2001.

[4] Executive Office of the President, Office of Management and Budget "North American industry classification system, United States 1997," Bernan Press, 1998, 1247 p.