The Role of Steel in the US Economy: Decomposing the 1982-1997 Forward and Backward Linkages of the Steel Industry

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ABSTRACT

This paper queries the benchmark input-output tables of the United States for 1982, 1987, 1992, and 1997 to examine both the industries that provide goods and services to the steel industry and the destination of steel products to other industries and final goods. This study provides a sense of how the industry changed from 1982 to 1997 and will aid in evaluation of new technology adoption by linking steel products to final consumers.

The steel industry is one of the major producers of raw materials for industry and construction. Value of shipments in 2000 for the steel industry amounted to more than $70 billion. This paper highlights the interdependency of the various steel-using industries of the economy. It shows the downstream use by industry of steel as a commodity. It shows the response in the use of steel to industry-specific shocks to national final demand. It also documents the steel intensity of other industry sectors in the economy.

The paper builds on the benchmark input-output tables to develop economic impact models. The effects both of industry final demand on steel and steel's final demand on industry are presented. The paper provides historical context to the observations and trends reflected in the examination of the data.

Methodology

The intent of the paper is to explore the following set of questions:

- What is the pattern of industry purchases of steel output?
- How has the distribution of steel purchases across industries changed over time?
- How much additional steel would be purchased per dollar of increased final demand in each industry?
- What are the interindustry output impacts per dollar of increased final demand for steel?
- What factors contribute to the trends identified?

To investigate the relationship of the steel industry to the rest of the economy, we relied on an input-output (I/O) modeling approach. National input-output models were constructed from the Bureau of Economic Analysis' (BEA) benchmark I/O accounts for 1982 (BEA 1991), 1987 (BEA 1994), 1992 (BEA 1997), and the 1997 accounts (BEA 2002). We employed versions of the models having a fully disaggregated industry structure in an effort to accurately specify the sub-industries making up the primary steel industry. The I/O sectors that make up the steel industry match the four Standard Industrial Classification (SIC) industries that are associated with the steel industry: 3312, Steel Works, Blast Furnaces and

Rolling Mills; 3315, Steel Wire Drawing; 3316, Cold Rolled Steel Sheet Strip and Bars; and 3317, Steel Pipe and Tubes.

Note that the 1997 accounts use the North American Industrial Classification System (NAICS) industry sectoring scheme. Although the NAICS was designed as a departure from the SIC system, based on examination of Bureau of Census (2000), the steel sector as defined in this paper shows no significant effect from the reclassification. This includes the classification of wholesale trade in steel (Metals Service Centers and Offices). The reclassification would be expected to affect many of the other industries represented in the IO structure. Effects would be more apparent looking at fully disaggregated results, but some of the results presented show these "reclassification" effects and will be further discussed. All the results presented in the paper are highly aggregated in terms of industry detail. For a more complete discussion of the construction of I/O models from national data the reader is directed to the data and documentation available at the BEA website or one of various comprehensive texts such as Miller and Blair (1985).

Every 5 years, the BEA benchmarks the national input-output accounts using Census surveys to measure interindustry financial flows including the use of the output of each commodity as an input to each industry. The "use table" component of the input-output model captures these flows. These surveys also capture the creation of commodity output by each industry. The "make table" component of the input-output model captures these flows. Multiplying these matrices appropriately (BEA, 1998, Appendix H) provides a snapshot of the direct requirements for commodities faced by industries. Inverting this matrix provides a snapshot of the direct and indirect requirements (or total requirements) for commodity output from each industry. This resulting matrix calculates the multiplier effect on output associated with purchases made in any or all industries. For the sake of brevity, the precise methods used to construct these matrices are provided with each release of the BEA benchmark tables (BEA 1991, 1994, 1997, and 2002).

To determine the use of steel by the other sectors of the economy, we queried the use table for the value of commodity steel purchased by each industry for use in their production of industry output (reported in Table 1). To further describe the disposition of steel in the economy, we estimated the steel intensity of each industry in the national model. The steel intensity is represented by the fraction of the value of steel used as an input to the value of the total output of that industry (reported in Figure 1).

Next, using the properties of input-output models, we introduced a final demand shock to each of the 13 aggregated industries of the economy individually and calculated the response in the primary steel sector. To keep the model in disaggregated form for analysis required estimating a composite final demand vector for each of the 13 aggregated industries, based on the full disaggregated structure of each. Each I/O model was closed with respect to households to capture direct, indirect and induced effects. We closed each I/O model by adding a household consumption column and a labor payments row to the direct requirements matrix. This resulted in the calculation of which industries have the heaviest reliance on steel for satisfying changes in their final demand. The results have been aggregated and expressed in constant 1997 dollars, where appropriate.

Results

Table 1 illustrates the use of steel as input into other major industries of the economy and to final demand for the four benchmark years respectively. In all years, five industries dominate the use of steel – primary steel, machinery, fabricated metal products, motor vehicles, and construction.

The well-documented financial problems of the domestic steel industry typically get attributed to the availability of relatively inexpensive imported steel products. Examination of the I/O data confirm this relatively large imbalance between exports and imports of steel, as the net flow of steel has averaged an import of about $11 billion across the benchmark periods in real terms.

Table 1. Use of Commodity Steel by Industry, 1982-1997

Steel Using Industry	Flow of Steel Output ($MM 1997)			
	1982	1987	1992	1997
Primary Steel	9,149.4	8,959.9	12,432.7	18,290.7
Other Primary Metals	1,192.6	1,187.3	1,663.1	5,863.8
Fabricated Metal	23,641.9	18,487.8	21,105.8	20,494.3
Mining	1.4	300.6	1,563.1	2,506.5
Construction	12,860.0	9,511.7	4,410.0	7,809.8
Wood/Paper	1,899.3	1,817.1	2,192.3	548.8
Chemicals	615.4	416.8	785.5	1,405.5
Stone/Clay/Glass	150.5	370.4	449.8	607.6
Tools/Hardware/Instruments	7,484.2	7,870.8	8,254.0	4,554.9
Machinery	21,875.1	12,519.9	13,713.7	22,414.0
Motor Vehicles	8,055.5	8,012.1	10,010.4	18,636.5
Transportation Eq. NEC	1,828.6	1,101.8	1,673.4	2,428.4
Net Exports	-13,845.4	-10,787.7	-7,385.9	-12,576.0
Other Final Demand	-4,570.2	1,395.1	-188.7	3,373.1
All Other/Miscellaneous	1,161.0	854.5	1,122.6	6,500.0
Total Steel Commodity Output	71,499.3	62,018.0	71,801.6	102,857.9

Figure 1 depicts the distribution of industries by their use of commodity steel. Of particular note, the number of industries at the more steel-intensive end of the distribution – those purchasing more than 10 cents per dollar of output – has declined markedly and steadily since 1982. This will be addressed further in the Discussion section.

Table 2 provides information about the steel industry's use of inputs to production of output. Essentially it provides a linear representation of the aggregated industry production function. Perhaps the most noticeable trend is the significant decline in payments to labor inputs (employment compensation) across the benchmark periods. The advent of high-quality foreign steel products at relatively low prices has resulted in 20 years of upheaval in the steel industry as the industry has become more efficient, adopted revolutionary technologies, and cut labor costs. These changes have resulted in significant reductions in industry employment. The move away from integrated mills toward mini mill steel

production has also resulted in the significant lowering of labor costs, as most mini mills are nonunion and less labor intensive. This will be discussed further in the Discussion section.

Other trends become evident by examining Table 2. The advent of mini mill technology adoption is manifested in the dramatic increase in the use of scrap as a steel input in the 1997 benchmark. The steel industry also has steadily increased its use of its own commodity in its production. The increased use of steel as an input to steel production and the increase in the use of scrap, in large portion, account for the significant reductions in the use of transportation and trade as inputs.

Figure 1. Distribution of Industries by Their Use of Primary Steel (Steel Input per Dollar of Industry Output, 1997 dollars)

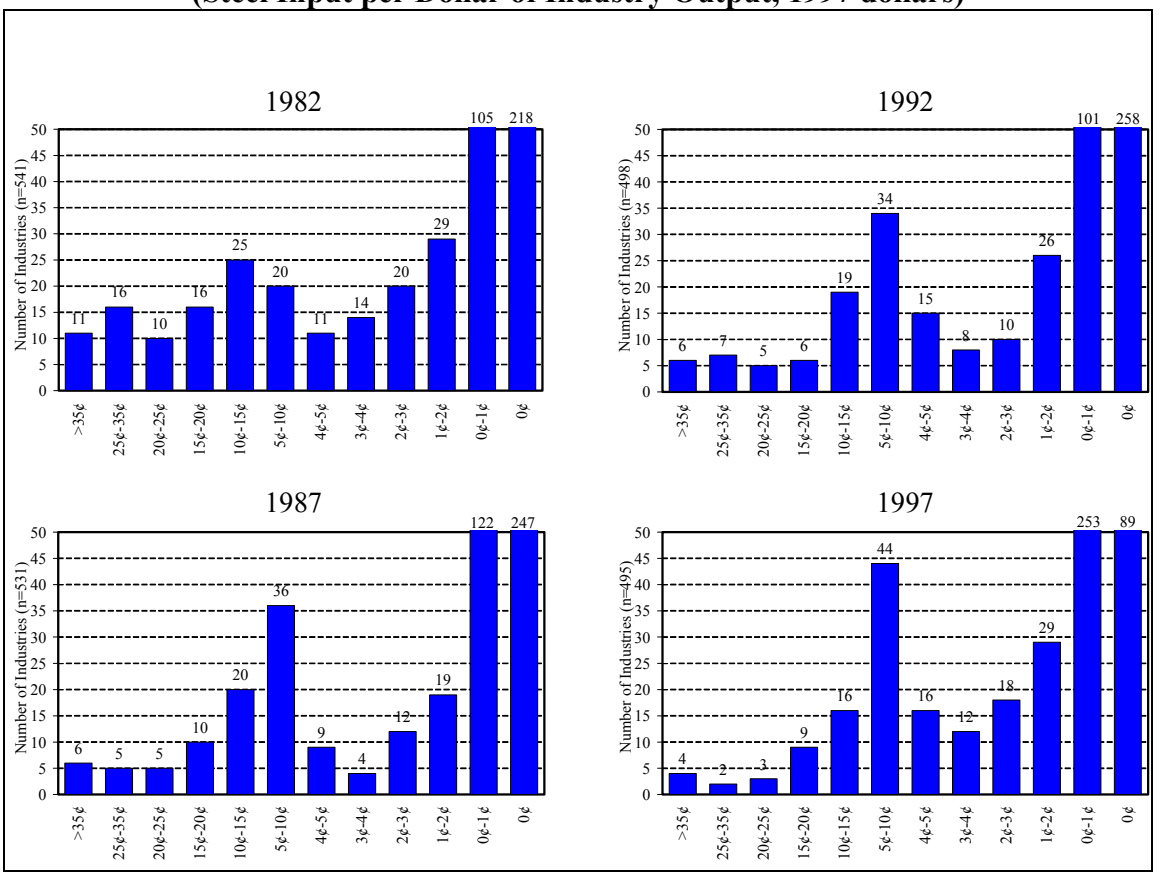


Figure 2 illustrates the effects on steel output generated by increased demands in each of the other industries represented. For example, in 1997, for each dollar of final demand from the motor vehicle industry, the steel industry would need to supply 8 cents of commodity output to satisfy that demand. Trends evidenced in Figure 1 gain more explanation looking at Figure 2. The use of steel is less concentrated by industry than it used to be. This corresponds to the decline over time of the number of industries using 10 cents or more steel per dollar of output. More industries are buying steel inputs to produce their output. The largest steel using industries have reduced their steel intensity, while most of the other industries have increased steel intensity.

Table 3 illustrates the changes over time in the effects of increasing final demand for steel. For example, in 1997 we estimate that increasing the final demand for steel by one

dollar would result in an additional $1.32 of economic activity as the direct, indirect and induced effects of the steel industry spending that dollar are calculated. This sums to about $2.32 of output generated in the economy. Thus we say that in 1997, the steel industry had an output multiplier of approximately 2.32.

Table 2. Commodity Inputs to the Steel Industry, 1982-1997

Commodity Input	Flow of Commodity Inputs ($MM 1997)			
	1982	1987	1992	1997
Primary Steel	9,149.4	4,036.6	12,432.7	16,784.3
Other Primary Metals	2,450.2	2,514.1	3,326.1	4,289.0
Scrap	1,448.6	2,505.0	2,247.6	10,323.8
Electricity	2,588.6	1,983.8	2,064.3	1,799.6
Natural Gas	2,261.5	1,770.4	1,115.0	926.6
Coal	1,845.6	1,395.2	1,339.8	2,682.8
Mining	1,523.6	1,843.2	2,207.6	3,022.2
Stone/Clay/Glass	520.6	1,116.2	1,144.8	1,669.2
Chemicals	4,939.4	1,747.7	1,186.3	2,072.2
Construction	1,613.4	1,243.4	497.4	194.7
Transportation and Misc. Ut.	2,024.7	2,107.1	3,723.0	787.4
Fabricated Metal	812.5	465.2	1,202.4	1,336.6
Machinery	2,089.5	995.0	1,822.0	3,122.5
Business/Professional Services	4,387.4	4,106.5	3,449.6	3,896.4
Trade	4,152.5	3,210.1	4,903.0	631.3
All Other/Miscellaneous	1,957.4	1,261.6	2,699.3	3,936.9
Employee Compensation	22,809.2	11,818.5	14,566.5	13,686.1
Other Value Added	-6,024.8	4,029.1	5,038.3	5,813.6
Total Steel Industry Output	60,549.3	48,148.7	64,965.9	76,975.2

Source: BEA 1991, 1994, 1997, 2002

Figure 2. Steel Output / $ Industry Final Demand, 1997 Dollars

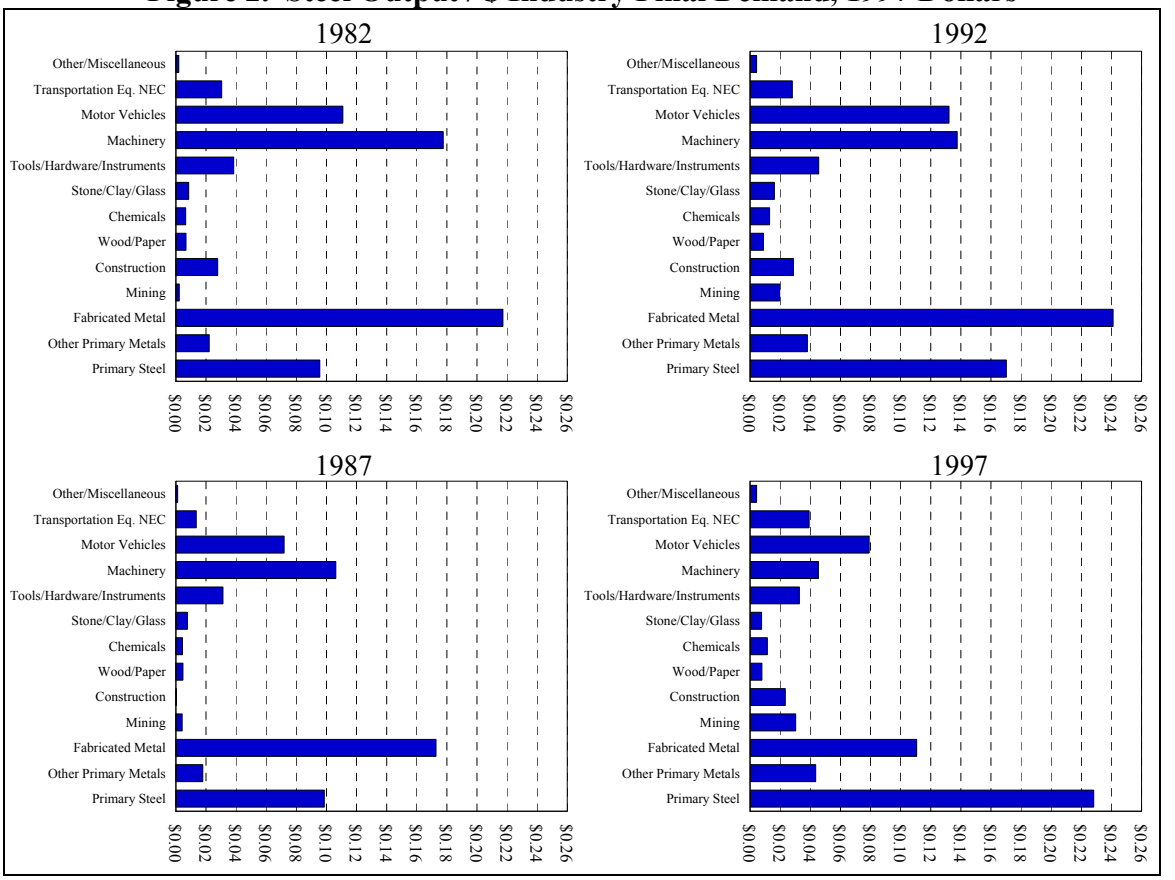


Table 3. Output Impacts per Dollar of Increased Final Demand for Steel, 1982-1997

Industry	1982	1987	1992	1997
Primary Steel	1.0830	1.0794	1.1411	1.2283
Other Primary Metals	0.0611	0.0589	0.1021	0.0828
Fabricated Metal	0.0168	0.0138	0.0331	0.0381
Mining	0.1365	0.0967	0.1635	0.1193
Construction	0.0286	0.0001	0.0323	0.0081
Wood/Paper	0.0094	0.0085	0.0181	0.0235
Chemicals	0.0947	0.0582	0.0691	0.0668
Stone/Clay/Glass	0.0088	0.0196	0.0316	0.0275
Tools/Hardware/Instruments	0.0185	0.0185	0.0375	0.0040
Machinery	0.0176	0.0147	0.0396	0.0725
Motor Vehicles	0.0030	0.0024	0.0077	0.0068
Transportation Eq. NEC	0.0009	0.0008	0.0017	0.0021
All Other Industries	0.4004	0.3574	0.6424	0.6412
Households	0.0139	0.0101	0.0165	0.0162
Steel Output Multiplier	1.8793	1.7291	2.3197	2.3209

Source: BEA 1991, 1994, 1997, 2002

Discussion

The analysis of the steel industry utilized the data and properties of I/O modeling to identify trends over the 1982-1997 period. Several of those findings merit more detailed explanation or development. We have researched these findings further and present them here. Of interest, much literature of use for researching the history and trends affecting the steel industry can be attributed to one side or the other of this highly politicized industry. While this provides perspective to independent research, it increases the difficulty of establishing definitive characterizations of the influences behind the trends observed.

International Trade Issues

Several studies document the effects of imported steel on the domestic steel industry. Although some would attribute all of the economic upheaval in the industry to the trade practices of other steel producing nations, the evidence in the literature suggests that trade issues only served to expose fundamental problems in the domestic industry. An early Department of Commerce Report (OBA, 1985) reports that imports increased from 2% of production in 1958 to 15% in the early 1970s, with these increases occurring mostly in years when labor contracts expired (every 3 years until the restructuring of the industry in the 1980s). The Environmental Protection Agency (EPA) succinctly characterizes the steel situation that developed over the 1980-1995 period (EPA, 1995). In the report to the President by the Department of Commerce (2000a), these issues are amplified and the case is made that steel, perhaps more that any other industry, has developed its operations subject to a variety of noncompetitive practices in this and other countries. Statistics from the Geological Survey (Kelly and Fenton, 2003) have been compiled into Figure 3. This figure illustrates domestic production of steel over time and shows the dramatic effect of several factors that came together to cut domestic production of steel beginning in 1982. Note that the domestic industry has not fully recovered to production levels seen prior to the recession of the early 1980's. During the 1980's and 1990's, spikes in steel imports are apparent, and imports in proportion to domestic production have been increasing steadily since bottoming out in about 1990.

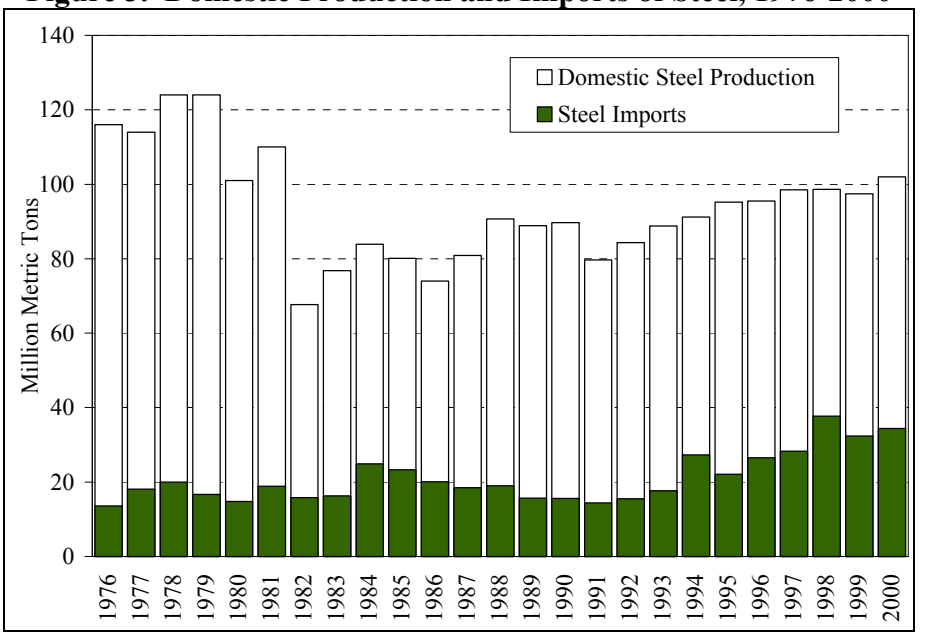
New Technology Impacts

Several studies document the adoption of electric arc furnaces for continuous casting and the success of the mini-mill in contrast to the demise of the large-scale integrated mill. Aside from imports, the development of domestic mini-mills has also caused upheaval in the steel industry over time, as these mills typically operate much more efficiently, have lower labor rates, and face dramatically lower legacy costs than large integrated mills (Berry, Ritt, and Greissel, 1999; EPA, 1995; OECD, 1989; and Department of Commerce, 2000b). These technology trends, coupled with the situation in the world steel trade have combined to reduce prices for steel products domestically. This has forced significant reductions in the operations of large-scale integrated mills and accompanying stiff reductions in industry employment.

In terms of the I/O benchmark years, these effects are seen in the apparent diversification of steel customers over time. As steel products become more cost-effective

and the number of available types of products increases, more industries become purchasers of steel output. This strengthens the interindustry linkages of the steel industry and results in greater impacts per dollar of final demand.

Figure 3. Domestic Production and Imports of Steel, 1976-2000



Source: Kelly and Fenton, 2003

NAICS Classification Effects

The conversion of industry classification systems from SIC to NAICS for the 1997 economic census and subsequent benchmark I/O study alters the distribution of dollar flows between industries compared to previous benchmarks. The change in methodology in some cases introduces discontinuities in the time series of various industries at the detailed level (former 3- and 4-digit SIC industries). The NAICS also introduces significant new industries not individually present in the SIC system. At the 2-digit NAICS level these include Information (Sector 51) and Management of Companies and Enterprises (Sector 55). The creation of the latter industry caused over $1.3 billion production inputs to the steel industry to be redistributed from other supplying industries where these processes were housed under the SIC system. Table 4 highlights industries backward-linked from steel that are likely influenced by some level of NAICS reclassification of detailed sectors. Though important to acknowledge the presence of these effects, we have not attempted to explicitly isolate specific effects of reclassification from any other inter-benchmark changes.

The table shows that relative to the average of the previous three benchmark IO studies, large drops in the use of trade and utilities in the 1997 IO study that would not seem to square with the otherwise large increases in input steel and scrap, for example. In part the drop in trade can be attributed to input steel that may have previously been accounted for under wholesale trade. The same could be said for input scrap. These results indicate that further analysis should attempt to perform some accounting of the explicit effects of the reclassification. These effects permeate the other aspects of the analysis (forward linkages and impacts), but have been discussed in the context of backward linkages only.

Table 4. Selected 1997 Commodity Inputs to Steel Showing Large Discontinuities with the Previous Three Benchmark IO Studies

Selected Commodity Input	Flow of Commodity Inputs ($MM 1997)						
	1982	1987	1992	1982-1992 Average	1997	1997 Change from 82-92 Average	Percent Change
Primary Steel	9,149.4	4,036.6	12,432.7	8,539.6	16,784.3	8,244.7	96.5%
Scrap	1,448.6	2,505.0	2,247.6	2,067.1	10,323.8	8,256.7	399.4%
Machinery	2,089.5	995.0	1,822.0	1,635.5	3,122.5	1,487.0	90.9%
Transportation and Misc Ut.	2,024.7	2,107.1	3,723.0	2,618.3	787.4	-1,830.9	-69.9%
Wholesale Trade	4,133.1	3,192.8	4,882.5	4,069.4	631.3	-3,438.1	-84.5%
Management of companies and enterprises	-	-	-	-	1,329.9	1,329.9	-
Total of Selected Sectors	18,845	12,836	25,108	18,930	32,979	14,049	74.2%

Source: BEA 1991, 1994, 1997, 2002

Timing of Benchmark I/O Tables

The benchmark I/O tables provide an annual snapshot of the domestic economy taken each 5 years. Though tremendously detailed, this snapshot only reflects economic conditions for the benchmark year. Having the data from the last four benchmarks begins to illuminate the trends we have suggested in this paper. However, having just four data points means that prevailing economic conditions in those four years affect the results we show and need more discussion. The effect of the timing of the benchmarks shows up generally, but most obviously, in the value-added and final demand components of the use tables.

In 1982, for example, the economy was in a significant recession. Figure 3 illustrated this with respect to steel production. Profits, shown in Table 2 as part of Other Value Added, were negative. The change in steel inventories, shown in Table 1 as part of Other Final Demand, also was negative in 1982. Because these anomalous negative values propagate to the summing of industry output and commodity output respectively, interindustry input intensities are correspondingly overstated for 1982 compared to other benchmark years. Further, in the fully disaggregated models, such anomalies and associated impacts on interindustry intensities are possible in various sectors for each benchmark. These effects are recognized, but no adjustments to models have been made, as this would require more detailed examination of all industries in each model.

Conclusion

We have examined the characteristics of the steel industry as reflected in the I/O analysis framework. We identify relevant trends apparent in the I/O data. We have mapped those trends to the historical development of the domestic steel industry over the 1982-1997 benchmark periods. The strength of the economy at any benchmark year is reflected in the

strength of the interindustry linkages (both in terms of number of linkages, and in terms of dollar flows per linkage). This has been shown for the steel industry in this paper.

We have noted several issues that affect the various benchmark studies including the 5-year-interval timing of the studies, the foreign trade situation in the steel industry, the pace of technological change, and the effects of discontinuities in trends imposed by the conversion of the 1997 benchmark IO study to NAICS sectoring. The questions posed in the Methodology section have been answered to the extent possible given the scope of the study and the issues and caveats discussed. We hope that this study illuminates some of the rich insights that can be gained by mining the benchmark IO tables across years. Yet this study also suggests the need for follow-up research on steel industry structure and economics, with emphasis on how the industry has fared over the course of the business cycle. This approach may also provide application to other industries that seek answers to the same set of questions about commodity inputs and outputs, and the impact of changes in final demands.

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