Journal of the Minnesota Academy of Science

Volume 47 | Number 2 Article 6

1981

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ABSTRACT — A large-scale model, SIMLAB, was used to project the iron ore industry through the decade of the 1980's for the state of Minnesota. This forecast shows that past trends in the industry are unlikely to continue through 1990, although output is seen to increase slightly during this period. Future studies will deal with different development scenarios to estimate the impacts of alternate future assumptions from this baseline trend analysis.

This paper reviews results of a forecasting project at the University of Minnesota, Duluth, assessing the iron mining industry of Minnesota to the year 2000. These projections were made with a large scale simulation model under various assumptions concerning the anticipated performance of the industry for the nation as a whole, the productivity of labor in the state of Minnesota's iron mining industry, and the anticipated Minnesota market share of total iron mining output of the United States.

This work joins a growing body of economic research on the iron mining industry for the state. There have been numerous attempts, direct and indirect, at analyzing and describing the future of this important state industry. Reports such as one by Arthur C. Barschdorf (July, 1968) are typical of some earlier efforts. That analysis of the future relating to the Iron Range area of Minnesota was conducted by calling upon key individuals and asking their opinions as to development trends for the region.

Another study funded by the Rockefeller Foundation (McNamara, 1976) discussed mining activity in the context of changes in output of ores and waste products as well as the use of capital, labor, transportation, and energy sources connected with metallic mining. More general than the earlier works, this study looked at some interrelationships between the mining industry and other sectors engaged in servicing this industry in the Lake Superior region.

Several other studies, such as those conducted by Michelson, Polta, and Peterson (1974) and the Minnesota Department of Natural Resources (1973), looked at iron ore reserve quantities and unit costs as well as state mineral policy, metal markets, and exploration and extraction techniques in an attempt to provide long-range information for policy development.

While these studies were useful in the context of trying to develop baseline and projected information sources for dealing with Minnesota iron mining, they generally stopped short of detailed analysis of the structure of this industry and its relationship to the rest of the U.S. economy. Although the Michelson paper did employ computerized modeling, the models were for the one purpose of analyzing iron ore availabilities and the relation to iron ore prices. The models did not simulate the relation between the iron mining industry and the rest of the regional or state economy.

One simulation model of the wider scope was developed on the St. Paul campus of the University of Minnesota by Wilbur Maki and others. The model is termed SIMLAB and is an input-output based program dealing with Minnesota industrial structure and the impacts of this structure on specific components of the state's economy. A large series of reports have been developed out of this work, projecting various sectors in the Minnesota economy into the future (Maki, et al., 1975, 1976, 1977). One recent effort (Maki, 1980) is especially important to the work being reported here. In that paper, Professor Maki incorporated a copper-nickel sector into the input-output based simulation model to forecast mineral development from 1970 to the year 2000.

This paper will review the important assumptions concerning future mineral development based on Maki's report. Next the general structure of the SIMLAB model is discussed. Maki's information base will then be updated through the 1970's in order to make new forecasts for the 1980's. Finally, the forecasts will be reported and implications will be drawn from those forecasts.

The Mineral Industries of Minnesota -- General Background

The mineral industries do not account for a very large share of Minnesota's economic activity. In the 1970's, the iron mining industry directly accounted for 1.4 percent of Minnesota's gross output, 1.0 percent of the earning of its work force, and only 0.8 percent of the total employed work force. However, this is the largest industry in northeastern Minnesota. Its economic effect upon the rest of the state can be seen only when the whole state economic structure is examined.

The dynamic changes in this industry have been awesome. The shift from natural ores to taconite production fundamentally affected the northeastern region of the state. That change reduced the seasonality of production, creating a more stable work force and economy. On the other hand, booming construction periods associated with expansion of the iron industry or changing technology intensified the

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cyclic instability of the region. Furthermore, the production of this industry is demanded by many durable goods industries which are sensitive to changes in aggregate economic activity. This suggests that local iron ore production will lag national production trends.

The future indications for this industry also promise great changes for northeastern Minnesota directly and the rest of the state indirectly. Several factors which will likely initiate these changes for Minnesota deserve review. First, U.S. import dependency, which increased substantially through the 1960's, appears to have dropped off and settled during the 1970's at about 34 percent of iron ore used in U.S. iron and steel plants (McNamara, 1979). It is, however, expected that rising import prices observed during the 1970's will likely continue, and the share of iron ore imports is likely to stabilize or decline.

Second, foregin competition from technologically advanced production plants in Asia and Europe are forcing the American steel industry to replace old high-cost facilities. New geographic location changes are open to the industry. One possibility involving a new technology is "direct reduction" of iron ore near the raw material site. If the new facilities were built in northeastern Minnesota, significant energy cost savings could be obtained. However, total consumer costs could increase when transport costs of finished steel products are totaled. In any case, this change is not expected to take place in the 1980's.

Another possibility for industry relocation is the possibility of construction on the Atlantic seaboard. There low-cost South American and African ores have high ore transport costs, but low finished-product transport costs. The use of the direct reduction process at the ore site, although promising in the context of "less-pure" future ore deposits, could result in either positive or negative impacts. But widespread introduction abroad of the direct reduction process also seems unlikely for the 1980's.

Third, the pricing environment for taconite inputs and outputs has changed substantially. Although taconite dropped in terms of price in constant dollars during the 1960's and 1970's, the price index rose substantially by 1973. This price change corresponded with the devaluation of the U.S. dollar in February of that year. Moreover, the price of energy has risen substantially during the 1970's; the manufacturing sector reduced its share of total energy needs by shifting them backwards in the form of taconite processing. The net result of these changes was to hold iron ore importation constant during the 1970's and to keep the domestic price of steel high relative to previous production. It is expected that these trends will continue into the 1980's.

Fourth, the 1977 Minnesota legislature established a new tax environment for the mining industry. The basic tax levy has been "indexed" to the industry price for taconite. The result has been a substantial rise in collection of total occupational, production, and royalty taxes. These taxes exceeded $500 million for the ten-year period starting in 1970. Assuming a five percent growth rate in the price of taconite pellets, the projected tax revenue for Minnesota in the 1980-89 period could be as high as $1.7 billion. Although a large portion of these tax revenues have been redirected toward regional, environmental, and economic development agencies, these taxes could place the region in a competitive disadvantage in the future.

The SIMLAB Model

As the forecasting device for future mineral development and its effects on northeastern Minnesota and the rest of the state, Wilbur Maki's laboratory simulation model, SIMLAB, is constructed from secondary data sources and is an innovative extension of the basic input-output format. Besides the industrial demand multipliers found in input-output studies, appropriate ratios depicting such things as labor requirements per dollar of output, productivity of labor in terms of output, and labor migration in terms of labor requirements compared to labor availability are incorporated into the forecast through mathematically interrelated modules.

SIMLAB includes nine such modules, of which three can be found in a conventional input-output table. They are: (1) the demand module, which constitutes the final demand portion of the input-output table; (2) the production module, made up of the demand multipliers of a Leontief inverse matrix; and (3) the income module, which constitutes the value added or final payment sectors of an input-output table. The remaining modules are: (4) the market module, relating the SIMLAB data base to the rest of the nation; (5) the investment module, showing the capital/output requirements for each industry; (6) the employment module, containing employment/output ratios and relating the production module to the labor force module; (7) the labor force module, containing information on the occupational composition of the labor force and relating the employment module to the population module; (8) the population module, containing data on births, deaths, and migration patterns and linking the employment and labor force modules; and (9) the household module, combining employment, labor force, and population information to determine housing stock and future housing requirements. This last module is presently being introduced into the model.

SIMLAB is a recursive model in the sense that the outcome of a given year's activities becomes the basis for the following year's inputs. The modules interact, but the impact-accounting is determined simultaneously. The complexity of the model forces consistency in the projections between the modules. For example, output cannot expand beyond the employment and capital availabilities in the region.

The Iron Ore Industry Structure in Terms of SIMLAB

The following discussion examines the structure of the iron ore industry in the context of the SIMLAB paradigm. Iron ore beneficiation requires intensive inputs of energy. Electricity is used for electromagnetic separation of iron-bearing material from waste rock. Natural gas is used to fire kilns which harden taconite pellets. Since Minnesota has no natural gas, coal, or petroleum reserves, a future peat-gasification demonstration plant to produce synthetic natural gas has been proposed. A fully operational plant could supply one-fourth of Minnesota's natural gas needs (Michaelson, et al., 1974). If this development is successful, the implications for taconite production are obvious.

The construction industry also provides inputs for maintenance and repairs as well as for expansion of capacity. Transportation expenditures include taconite pellet storage, docks, and harbor facilities. The machinery industry provides equipment for ore production. Petroleum requirements are primarily in the form of diesel fuel and lubricants. Minnesota's primary iron and steel producers chiefly supply the

grinding balls used in taconite ore production. These industries provide approximately 80 percent of the industrial requirements of the taconite industry. In 1970, these industrial inputs amounted to approximately $2.20 per ton of pellets, which were priced at $16.40 per short ton. Another major Minnesota input, labor, amounted to an additional $2.15 per ton of taconite produced. Transportation costs, based on transporting Minnesota ore to the lower lakes by rail and lake carriers, can be estimated at between $4.10 and $8.20 per ton, depending upon destination (Minnesota DNR, 1973). Clearly, transportation costs are central to a plant relocation decision.

In examining the structure of the taconite industry, of particular interest are the industry demand multipliers. The total effect of a $1 increase in iron ore exports on all industries is an increase of $1.33, where the 33 cents is the direct and indirect effects on the other industry output totals. The national demand multiplier for iron ore production is $1.69. The difference between the Minnesota and the national multiplier is due to Minnesota's dependence on out of state energy and private financial resources for this capital intensive industry. While this short-term multiplier is low, most mineral industries are similarly low. However, the long-term effect for this industry (and most mineral industries) is substantial.

This result exists because of a large value added component in the form of high wage and salary payments to employees and tax payments to state and local governments. These induced effects occur when both forms of income payments are recirculated within the local economy. When the table is closed and the taconite industry interacts with its input-supplying industries and with the household sector, the long-term demand multiplier is $3.08. This large complex of industry and households has a long-term impact two to three times larger than the corresponding short-term impacts. This suggests that the importance of the taconite industry is greatly underestimated if the industry's whole structure and its long-term impacts are ignored.

Recent and Future Trends in U.S. and Minnesota Iron Ore Industry

The iron ore industry cannot be listed as one of this nations growth industries, based on the trends of the past ten years. In fact, the value of output of iron ore, measured in constant 1970 dollars, dropped from $944 million to $929 million between the years 1970 and 1979 while the average yearly rate of growth was still a positive two percent. This is a comparatively low rate of growth relative to most other U.S. industries. Minnesota, on the other hand, fared slightly better than the national pattern, with a net increase of 14 percent between 1970 and 1979, from $571 million to $649 million, again in 1970 dollar terms. The average annual rate of growth in output for Minnesota's iron ore industry was five percent. The largest increases in output for the state were in the years 1973 (24 percent) and 1978 (72 percent). The largest years of decline were 1975 (17 percent) and 1977, a strike year in the local industry, (23 percent). The data for both the U.S. and the state of Minnesota indicate a cyclical nature of the industry.

Another interesting trend is the change in market share of Minnesota ore relative to that of the nation. The Minnesota share has steadily increased at an average annual rate of two percent. The 1979 market share was 15 percent greater than the 1970 market share, again indicating the trend of increasing importance of Minnesota during the decade of the 1970's. The 1970 market share was 61 percent, and by 1979 the market share increased to 70 percent. This indicates Minnesota's improved competitive position.

Employment in this essential industry has also increased in Minnesota over the ten-year period from 13,300 employees in 1970 to 15,300 employees in 1979, an increase of 15 percent over the decade. One interesting statistic, however, has been the rate of change in output per worker--a measure of labor productivity. In absolute terms, the output per worker declined by approximately one percentage point during the decade for the state of Minnesota, from $43,000 to $42,500 measured in constant 1970 dollars. Again, however, the average annual rate of change was positive and increased by one percent over the decade.

These figures were substituted into SIMLAB to simulate the performance of the Minnesota economy through the 1970's. It should be recognized that this means that all other trends and patterns in the variables and parameters of the SIMLAB system have not changed but that their absolute values had changed.

For the 1970's the simulation assumes a two percent annual rate of growth in output at the national level, a two percent annual rate of change in regional market share of that national output, and an increase in labor productivity equal to one percent per year. The employment levels are computed, and not assumed, from these other patterns of change.

These trends were then adjusted downward to give a picture of the 1980's under a more realistic set of assumptions. For instance, the national trend in steel production has been impaired by the move toward smaller cars and the substitution of lighter materials in automobiles. Similarly, the use of electric arc furnaces favors the use of scrap and has led to a greater regional decentralization in production away from the Great Lakes region. Both of these trends bode ill for national output levels and regional market share for the 1980's. Accordingly, we have assumed a zero percent annual rate of growth in output at the national level, a zero percent annual rate of change in regional market share of total U.S. output, and an increase in labor productivity equal to only one-half of one percent per year.

With this high option forecast, output increases by nearly one-half over the decade of the 1980's. Output capacity is never reached and, therefore, need not be increased. Employment increases a little over two percent in the region in this industry during the ten-year period.

More specifically, output increases from $572 million in 1970 to $836 million in 1985, measured in constant 1970 dollar terms. This represents a 46 percent increase in output over the fifteen-year period. It should be pointed out that the data for 1970 and 1979 were simulated on the basis of actual growth trends in the industry. These same trends were then adjusted downward for the 1980's. The growth trends show excess capacity in the region for the entire period. After that time, new investment would be required to maintain the trend.

Regional employment in the industry is shown to increase from 13, 153 in 1970 to 16,831 in 1985. This represents only a 28 percent increase in regional employment, attributable to increased regional output. The rest of the output is made up in projected increases in labor productivity as the newer technologies introduced into production during the 1970's generally take hold in production of the 1980's.

One interesting sidelight to this analysis is the effect of

these projected trends on the other industries in the region. As previously noted, SIMLAB is driven by the standard input-output model developed by Leontief. This means that projected changes in the mining industry will directly and indirectly affect other regional industries through the multiplier process.

Just selecting one specific industry out of 55 possible in the SIMLAB input-output model, retail trade is greatly affected by increased mining activity. The gross output of this industry is seen to increase from a level of $3 billion in 1970 to $5 billion in 1985, in 1970 dollar terms. This represents a 46 percent increase in real activity, resulting from a increase in mining activity plus the normal trend of retail activity apart from mining. The increase in employment for that same 15-year period would be from a total of 270,000 to 333,000. This represents a 23 percent increase in employment, reflecting such things as productivity changes and capacity excess built into the model.

Projecting the same trends to 1990 finds iron ore output increasing further to $853 million. Employment grows only slightly to 16,748 due primarily to low increases in labor productivity for the region. By 1990, the new technology introduced into taconite production on the Range will generally have been adopted.

Which suggests some caveats concerning the forecast. This high option forecast assumes that iron mining growth trends will be very low, but not negative. This is the simplest assumption that could be made about the performance of iron mining in the state of Minnesota. Although this assumption has been repeated a number of times, its importance cannot be stressed enough. Forecasts represent a first step in a total research design, the step of discovering what would occur under an optimistic set of projections. Projections like this serve as a basis for comparison when more realistic future assumptions can be incorporated. Trend analysis has its own usefulness in that it gives a limiting case. These figures represent the current best estimates based on a ten-year trend pattern during the 1970's and revised into the 1980's. Alternate assumptions concerning those trends in the 1980's will be examined in future papers.

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