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QUARTERLY ECONOMETRIC MODEL AND OFRECASTS OF THE MINNESOTA AND U.S. IRON MINING INDUSTRY

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Abstract

This publication was prepared as Appendix D of the resport to the U.S. Bureau of Mines entitled, "The Economic Importance of the Mineral Industry in Minnesota". This section of the report projects quarterly production and stock levels for the Minnesota and U.S. iron mining industry to the year 2000. Projections of Minnesota's iron industry employment are subsequently derived from the production forecasts. Ordinary least squares regression techniques were used to analyze the seasonality patterns that existed between 1955 and 1978. The regression equations, based on the quarterly data, were calibrated so they could be used to seasonalize the annual iron ore consumption, production and import projections developed by the U.S. Bureau of Mines. Alternate industry forecast series are presented to facilitate comparison with the yearly baseline projection series.

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Introduction

A quarterly econometric model of the U.S. iron mining industry was constructed as an initial step in the assessment of the present and future importance of the mineral industry in Minnesota. This model was used to correlate several quarterly time series for the 1955 to 1978 period. The salient feature of this period was the industrywide shift from natural ore to taconite production. The shift to taconite occurred as a result of the adoption of a new technology in iron ore processing which had been developed earlier at the University of Minnesota's Mineral Resources Research Center. Low grade taconite became cheaper to process than high grade natural ores.

The shift in the technology of iron mining was accompanied by a corresponding reduction in the seasonality of employment and production. Taconite production became a year-around activity which caused shifts in the quarterly levels and locations of iron ore stocks. These changes compensated for the lack of year-around shipping of iron ore produced in Minnesota. Increases in taconite production were dependent on the construction of new taconite processing facilities. As these facilities expanded, taconite production gradually increased, but only enough to replace the reduced levels of natural ore shipments. Iron ore imports to the U.S. increased from 23.5 million long tons in 1955 to 45.7 million long tons in 1975.

Forecasts of iron ore production show a near doubling of Minnesota production from 55.2 million long tons in 1978 to 101.3 million long tons in 2000. This projected increase in iron ore production is in response to a projected 74.8 million long ton increase in annual U.S. demand for iron ore. The increase in demand would be accompanied by a slight rise in imports from the 1978 level of 26.2 million long tons to a forecast 2000 level of 30.6 million long tons.

Iron Ore Production

The history of Minnesota iron ore production is characterized by two long periods of increase (wth an all-time peak reached in 1950, followed by another period of decline and a third period of increase starting in 1960. Total iron ore production in Minnesota increased from 56.8 million long tons in 1960 to 60.1 million long tons in 1973 (Table D.1). Due to a recession-induced decline in U.S. iron ore demand, production levels declined slightly during the 1973-1976 period. In addition, the industry experienced a miners strike during 1977. For this reason Minnesota production dropped to 31.3 million long tons that year, its lowest level in decades.

Table D.1

Estimated Annual Consumption and Supply of Iron Ore in the U.S., by Source, 1955-1978.[1]

Year	Consumption[1]	Net Change in Stocks[3]	Total Supply[1]	Net Imports[2]	Domestic Production Total[2]	Domestic Production Minnesota[3]	Domestic Production Rest on Nation
	(thousand long tons)						
1955	130,632	2,192	128,440	23,467	104,973	69,945	36,028
1956	124,415	-2,644	127,059	30,356	96,703	60,667	36,041
1957	118,559	-19,366	137,926	31,928	105,997	68,097	37,900
1958	93,775	-2,774	96,549	28,582	67,967	41,400	26,567
1959	91,921	307	91,614	32,639	58,975	35,200	23,775
1960	104,828	-12,197	117,025	29,387	87,638	56,800	30,838
1961	96,556	4,689	91,867	20,859	71,008	43,200	27,808
1962	97,831	2,646	100,477	27,861	72,616	45,500	27,116
1963	104,216	5,628	98,588	25,837	72,751	45,100	27,651
1964	123,887	7,076	116,811	35,454	81,357	48,900	32,457
1965	127,150	1,709	125,441	38,021	87,420	52,500	34,920
1966	127,928	-1,257	129,185	38,481	90,704	55,000	35,704
1967	122,014	-1,078	123 092	38,897	84,195	49,700	34,495
1968	122,430	-533	122,963	38,003	84,960	51,900	33,060
1969	128,892	4,346	124,546	35,305	89,241	54,900	34,341
1970	125,956	-3,185	129,171	39,380	89,791	56,700	33,591
1971	111,635	-8,226	119,861	37,563	82,299	51,934	30,365
1972	121,328	11,752	109,576	33,660	75,910	49,297	26,618
1973	135,335	7,515	127,820	40,586	87,234	60,120	27,108
1974	132,169	-1,785	130,384	45,706	80,316	59,410	25,268
1975	114,068	-10,451	124,519	44,203	80,316	52,361	27,955
1976	113,821	-6,922	120,743	41,476	79,316	49,797	29,470
1977	106,671	15,645	91,026	35,641	55,385	31,256	24,129
1978	110,920	4,051	106,869	26,151	80,718	55,228	25,490

1/ Consumption is equal to total supply plus the change in stocks. Total supply is equal to net imports plus total domestic production.

2/ U.S. Department of Commerce, Survey of Current Business, January, 1956-1979, page 532 and April 1979, page 532.

3/ U.S. Department of the Interior, Bureau of Mines, Preliminary Area Reports (Minn. 30) and the Mineral Industry Survey series.(see reference 8).

Natural ore production in Minnesota declined from peak levels during the early 1950's when it was 100 percent of the State's total iron ore production, to 10.3 million long tons in 1975, when it was 20.2 percent of total iron ore production. During this period of declining natural ore production, Minnesota's share of total U.S. iron production remained at about 65 percent while its share of total world iron ore production declined from 18.7 percent to 5.8 percent. The decline in Minnesota's share of domestic natural ores production can be attributed to the exhaustion of available high grade natural ores, the introduction of the taconite refining process, and the availability of the domestic market to imports.

Shift From Natural Ores to Taconite

Elemental iron is found in numerous types of ores. These ores vary greatly in physical nature and chemical structure. As a result, the extraction and purification technologies applicable to each ore type is unique. Prior to 1955 nonmagnetic goethite and hemitite ores, often referred to as 'natural ores', accounted for practically all of the elemental iron extracted in Northeast Minnesota. Before World War II the iron content of these ores was usually well above 50 percent by weight in its naturally occuring state. The high iron concentration made it feasible to ship these ores to steel mills after little or no processing at the mine site. Further concentration prior to shipment was desirable but the nonmagnetic, impermeable nature of these ores made it difficult to separate the iron from the ore in any other way than by furnace. After World War II the sources of the very high grade ore had been depleted significantly. As ore quality decreased, cyclones, sink floats, spiralling and heavy media separators, and numerous other techniques were employed to boost concentration before shipment (1). This resulted in higher production costs.

In 1955 Reserve Mining Company implemented the taconite pelletization process commercially. Table D.2 shows how taconite pellet production has helped phase out the demand for natural ores since that time. Already in 1968 taconite production surpassed natural ore production. Although natural ores still contributed 8 percent in 1978, it is expected that virtually all such operations will close within the next 20 years due to rising production costs.

Taconite pellets have two major advantages over natural ores. Contrary to concerns over the supply of high grade natural ores, exhaustion of taconite ore reserves is not an eminent problem. In its natural form, taconite ore is only around 25 percent iron by weight. This ore is common in Nrotheastern Minnesota according to the most modest reserve estimates.

The second advantage held by taconite is really a groupd of advantages, all of them related to the ore's chemistry. Hard, rock-resembling taconite may be finely ground to allow the magnetic separation of iron from much of the rock. The remaining 60 percent pure ore is heated in kilns to form hard, pea-sized pellets. In this state the taconite ore that is

Table D.2

Types of Iron Ore Produced in Minnesota, 1956-1978.1/2/3/

Year	Total	Taconite	Natural Ores
		(thousands of long tons)	
1956	60,667	5,142	55,525
1957	68,097	6,881	61,216
1958	41,400	8,600	32,800
1959	35,200	8,190	27,010
1960	56,800	11,925	44,875
1961	43,200	13,884	29,316
1962	45,500	14,468	31,032
1963	45,100	16,733	28,367
1964	48,900	18,985	29,915
1965	52,500	10,360	42,140
1966	55,000	21,797	33,203
1967	49,700	24,105	25,595
1968	51,900	29,935	21,965
1969	54,900	33,155	21,745
1970	56,700	35,740	20,960
1971	51,934	34,199	17,735
1972	49,297	34,768	14,529
1973	60,120	42,074	18,046
1974	59,410	41,545	17,865
1975	52,361	41,784	10,577
1976	49,797	40,355	19,442
1977	31,256	26,573	4,683
1978	55,228	50,720	4,508

1/ The annual totals used were those obtained from the U.S. Department of Commerce, Survey of Current Business (see reference 2/Table 1.1). These figures were not identical to those listed by sources 2/and 3/ of this table. Only the percentage distribution between taconite and natural ores was obtained by sources 2/ and 3/.

2/ Values for 1956-1971: U.S. Bureau of Mines, Mineral Industries Survey; 1957-1972.

3/ Values for 1972-1978: U.S. Bureau of Mines, phone conversation with F.L. Klinger.

shipped to blast furnaces is of a higher concentration than most natural ores. Since iron refining is a weight-losing process, large savings may be realized in the long run by shipping 60 percent pure pellets, rather than natural ores of at most 50 to 55 percent iron content. This is especially true since high grade natural ores are becoming marginally harder to find and costlier to mine(6).

In comparison to natural ore processing, which employs a comparatively negligible amount of treatment, the taconite pelletization process is extremely energy intensive. Production-related fuel use of taconite producers is typically more than 2.5 times that needed to produce shippable natural ores(2,3). The magnetic separation stage requires large amounts of electricity, while the fusion (pelletization) process relies on natural gas heating. Substantial capital requirements are needed both for the process and in order to generate the needed energy. The higher mine site costs of taconite production methods are justified in the overall iron making process. In order to determine which of the two procurement systems is optimal, the analysis must be followed through to the "point of indistinction" (3). In this case the point of indistinction is the physical state in which it no longer matters which ore type a given quantity of molten iron originated from. Kakela showed that the additional energy and capital costs incurred at the mine site were more than compensated by saving at the blast furnace.

The superior furnace efficiency of taconite ore is a result of several of its chemical properties. The main factor is the higher permeability of taconite pellets. This characteristic promotes more effective fuel and air circulation within the furnace. Another advantage taconite pellets possess is their high energetic content. In effect, part of the energy used at the mine site helps boost the energy content of the pellets. The bonding of natural ores to water also raises heating, hence energy, requirements. An obvious factor is that the taconite pellets are more concentrated than natural ores. By finding a method for using the relatively abundant taconite ore, domestic producers helped curb the need for future increases in imports. Even though technological progress made a low grade ore more economically viable than the high grade ore, imports have played an increasingly important role since the end of World War II.

Growing Import Dependency

The largest increase in net imports since World War II occurred during the first ten postwar years. Imports rose from 2.8 million long tons in 1946 to 23.5 million long tons in 1955, an average annual increase of about 26.5 percent. 1/ During these years high grade natural ores were hard to obtain, and the taconite refining process had not yet been implemented. Imports helped bridge the gap between domestic demand and domestic supply. Ever since the introduction of the taconite processing method,

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1/ U.S. Department of Commerce, Survey of Current Business, January 1947-1948 and 1956-1957, page S-32.

iron ore import levels have not risen significantly. The data show that the average annual import levels for the 1955 to 1959 and 1974 to 1978 periods were 29.4 million long tons and 38.6 million long tons, respectively. This is equivalent to a 1.4 percent average annual increase over the twenty year period. This rate of increase is significant, but is quite small compared to the rate experienced between 1946 and 1955.

Imports reached an all time peak in 1974. Since then the amount of iron ore supplied by foreign sources has steadily declined. U.S. Bureau of Mines projections, Table D.3, show domestic ore production increasing enough to force imports to gradually decline from levels over 40.0 million long tons per year during the 1973 to 1976 period to 30.6 million long tons per year by 1993. This level is expected to prevail at least until the year 2000. One major reason for continued imports lies in the lower production costs in effect in some of the other iron ore producing nations.

Although Northeast Minnesota has been the largest single source of iron ore in the U.S. for decades, a near doubling of ore production in the rest of the nation is also needed if imports are to be reduced to 30.6 million long tons per year by the 1990's. Vast capital expenditures will be needed to effect such a capacity increase.

For all practical purposes, 100% of the iron ore produced in Northeast Minnesota is exported from the region. For this reason iron mining and related industries are important in determining the region's employment and income levels. A substantial portion of the revenue generated by the sale of ore (or subsequently derived products), is spent within the region. This direct spending takes the form of income payments to employees or payments to local contractors. Much of this direct spending is eventually respent within the region by the initial recipients. This multiplier effect further amplifies the regional impacts of the initial financial inflows. It is probable that this region will continue to rely heavily on the iron ore industry, both as a source of employment and as a component of its economic base.

Table D.3

Projected Iron Ore Production, Imports and Consumption, United States and Minnesota, 1979-2000. 1/

Year	United States Production	Imports	Consumption	Minnesota Production
	(mil. tons)			
1979	88.6	43.4	132.6	63.9
1980	91.4	42.7	134.8	65.6
1981	94.2	42.0	136.9	67.0
1982	97.1	41.3	139.1	68.5
1983	100.0	40.5	141.3	70.0
1984	103.1	39.7	143.6	71.6
1985	106.2	38.8	145.9	73.1
1986	109.4	37.9	148.2	74.8
1987	112.7	37.0	150.6	76.4
1988	116.0	36.1	153.0	78.1
1989	119.4	35.0	155.5	79.8
1990	122.9	34.0	157.9	81.5
1991	126.5	32.9	160.5	83.3
1992	130.1	31.8	163.0	85.2
1993	133.9	30.6	165.7	87.0
1994	137.7	30.6	168.3	89.0
1995	140.4	30.6	171.0	90.9
1996	143.1	30.6	173.7	92.9
1997	145.9	30.6	176.5	95.0
1998	148.7	30.6	179.3	97.0
1999	151.6	30.6	182.2	99.1
2000	154.5	30.6	185.1	101.3

1/ U.S. Department of the Interior, Bureau of Mines, Mineral Commodity Summaries, U.S. Government Printing Office, Washington, D.C. The projections of future United States iron ore consumption and imports of iron ore are based on information supplied by F.L. Klinger, U.S. Bureau of Mines, Washington, D.C. The projection of future Minnesota production was derived from information on the expansion plans of taconite firms compiled by the Minnesota Environmental Quality Board, Regional Copper-Nickel Study.

Building a Simple Forecasting Model: Model I

The iron ore consumed for steel production in the U.S. during any given quarter arrives from several sources. For the purpose of this report three distinct regions have been identified. Minnesota, the study region, has been separated from the rest of the United States. Mines located on foreign soil account for the third source of domestic iron ore supply.

The iron ore produced or imported into U.S. markets during a given quarter or year need not be consumed during the same time period. Stocks are used as a buffer between production and consumption. If at any time the amount of iron ore demanded by the economy surpasses the available supply, stocks will be utilized in the short run until domestic production or import levels can be raised. If the demand lags, producers will build up their inventories in anticipation of the next cyclical upswing. Stocks are held at mine sites, docks, and iron and steel mills.

Total U.S. consumption is equal to the sum of total domestic production, net imports, and the change in total stocks. Values of these variables for the years 1955 to 1978 are listed on a quarterly basis in Table A1 of Appendix A. The annual values were listed previously in Table D.1.

U.S. Demand for Iron Ore

Throughout the 1957-1978 period, quarterly iron ore consumption in the U.S. was relatively stable when compared with domestic production. Quarterly changes in stock levels made the more stable consumption levels possible. The shift from natural ores to taconite also helped reduce the seasonality in production.

During the 1957 to 1978 period, quarterly U.S. iron ore consumption, i.e., output demanded, had the following relation to GNP, a trend term, and seasonality:

$$\log_{10}OUTD_t = \underset{(.47922)}{2.92105} + \underset{(.18557)}{0.58575}*\log_{10}GNP_t - \underset{(.04520)}{0.09881}*\log_{10}t + X_q \qquad \text{Eq. (D.1)}$$

where, $OUTD_t$ = total U.S. iron ore requirements in millions of long tons in t-th period.

GNP_t = gross national product of the U.S. in billions of 1967 dollars in t-th period.

t = trend term denoting time, represented by subscript t and derived as follows: t = (Year-1957)*4+Quarter.

X_q = seasonality index for q-th quarter as follows:

Quarter I (January 1 to March 31) = 0.00000;
Quarter II (April 1 to June 30) = 0.02043 (0.02037);
Quarter III (July 1 to September 30) = -0.02695(0.02091);
Quarter IV (October 1 to December 31) = -0.04243(0.02135).

In the derivation of the coefficients, $R^2 = 0.72$ and $F = 20.3$, thus indicating a statistically satisfactory fit of the data to the model, which shows $X_2 > X_1 > X_3 > X_4$. 2/ All reported data are transformed into their logarithmic values to compute the non-linear relationships between OUTD and GNP. The standard deviation associated with each independent variable is shown in brackets.

The positive but small regression coefficient for GNP shows that the amount of iron ore demanded rises with GNP, but at a decreasing rate. This reflects the increasing efficiency in the use of iron ore per $1 GNP due to use of scrap steel and the increasing importance of iron and steel substitutes like plastics and aluminum to the economy. The slightly negative exponent on the trend variable further dampens the effect of GNP growth on the demand for iron ore. The first quarter of 1960 had a deflator of only 1.29 while the same quarter of 1975 and 1985 had deflators of 1.53 and 1.60 respectively. When the model was run without the trend term the exponent of GNP_t was reduced to 0.21923, while the constant rose to $10^{3.83841}$. This further proves the increasingly deflating effect of $t^{-0.09881}$.

The seasonality indices show an annual peak in the use of iron ore during Quarter II and a low during Quarter IV. In addition, the average Quarter I use rate exceeds that of Quarter III. Apparently slightly larger quantities of ore are refined into steel during the winter and spring quarters in order to supply upcoming construction projects usually undertaken during the late spring, summer, or autumn. Although the demand for steel expressed by the automobile industry may help even out the seasonal fluctuations in the output levels demanded, the relatively mild variations in production may also be attributed to the nature of the steel-making

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2/ It is recognized that the trend terms for any given year deflate the four quarters to different extents. Specifically, in any given year, the quarterly deflator, D_q, displays the following pattern: $D_4 > D_3 > D_2 > D_1$. Yet this effect does not significantly change the results. During the 1957-1978 period the average output demanded for the four quarters was

$\overline{QI}_{57-78} = 30,244.7$

$\overline{QII}_{57-78} = 31,524.6$ $\therefore \overline{QII} > \overline{QI} > \overline{QIII} > \overline{QIV}$

$\overline{QIII}_{57-78} = 28,496.8$

$\overline{QIV}_{57-78} = 27,327.7$

These figures exclude quarters in which strikes occurred.

process. Blast furnaces require huge capital investments. Due to the tremendous costs of capital depreciation it is not an attractive investment strategy to build enough furnace capacity to supply the peak season on a short term basis. This would force too high a percentage of the capital to be idle during the rest of the year. Another cost would be labor. In order to supply peak demand a large staff would be needed. During the rest of the year steel makers would face two options. They could maintain a large staff and face substantial productivity decreases or they could lay off large numbers of workers. This latter option would cause unwanted socio-economic and politican unrest. Because of these factors, it is generally less costly to produce steel at a near constant rate than to store the excess until it is purchased.

The historical model predicted that U.S. iron ore consumption would reach about 182.0 million long tons by the year 2000. In order to make the historical model reach the 185.1 million tons per year mark predicted by the U.S. Bureau of Mines it was necessary to inflate the constant term by the ratio, 185.1/182.0. This leaves the final model for predicting iron ore consumption in the following form:

$$OUTD_t = 1.01703*10^{2.92105}*GNP_t^{0.58575}*t^{-0.09881}*10^{X_q} \qquad \text{Eq. (D.2)}$$

The annual and quarterly projections are listed in Tables D.4 and D.1.3 respectively.

U.S. Production of Iron Ore

Quarterly data for the 1957 to 1978 period were also used to fit the equations needed for projecting iron ore production in the United States. These equations are presented in Tabel D.5. Output demanded, recent changes in production levels, a trend variable, and a series of dummy variables representing constant seasonal variation were included in the model. Each explanatory variable is defined as follows: 3/

- Output demanded lagged one quarter, i.e., U.S. consumption last quarter;
- Minnesota production lagged one minus five quarters, i.e., the difference between Minnesota's production level 1 and 5 quarters ago;
- Rest of nation production lagged one minus five quarters, i.e., the difference between the rest of the nation's production level 1 and 5 quarters ago;
- t, which is represented by: (Year-1957) * 4 + quarter;
- Dummy variables denoting constant seasonal differences.

3/ Although data are available for 1955 and 1956, all regressions have been carried out between 1957 and 1978. This was necessary because the construction of the lagged production variables required data for the previous two years.

Table D.4

Projected Annual Consumption and Supply of Iron Ore in the U.S., by Source, 1978-2000: Model I.

Year	Consumption[1/]	Net Imports	Domestic Production		
			Total	Minnesota	Rest of Nation
	(thousands of long tons)				
1978	131694.	47049.	84645.	59203.	25442.
1979	134478.	46801.	87677.	61207.	26470.
1980	137346.	46220.	91127.	63337.	27789.
1981	139646.	45267.	94379.	65314.	29065.
1982	142007.	44470.	97537.	67205.	30332.
1983	144430.	43708.	100721.	69116.	31605.
1984	146915.	42991.	103923.	71039.	32885.
1985	149461.	42310.	107152.	72981.	34171.
1986	151745.	41438.	110307.	74870.	35438.
1987	154080.	40628.	113452.	76750.	36702.
1988	156468.	39854.	116614.	78642.	37971.
1989	158909.	39111.	119798.	80551.	39247.
1990	161403.	38399.	123005.	82477.	40528.
1991	163579.	37459.	126120.	84336.	41784.
1992	165798.	36581.	129217.	86181.	43036.
1993	168061.	35735.	132326.	88033.	44293.
1994	170367.	34914.	135453.	89898.	45554.
1995	172716.	34119.	138598.	91777.	46820.
1996	175110.	33348.	141762.	93671.	48091.
1997	177548.	32602.	144946.	95580.	49366.
1998	180030.	31882.	148149.	97503.	50646.
1999	182558.	31187.	151371.	99441.	51931.
2000	185132.	30518.	154614.	101394.	53220.

1/ Consumption is equal to net imports plus domestic production; net stock changes in one calender year are assumed equal to zero.

Table D.5

Iron Ore and Taconite Production and Stocks Forecasting Equations: Model I.[1/]

Equation Dependent Variable	Equation	Constant Term	Dummy Variables First Qtr.	Second Qtr.	Third Qtr.	Fourth Qtr.	TIME	Output Demanded Lagged 1	Change in Minnesota Production Lagged 1,5	R^2	F
			(thousands of long tons)								
Production, Minnesota	Original	-2,300	--	8,606	10,147	2,760	--	0.331	-0.169	.70	37.7
	Final	-7,297	--	8,606	10,147	2,760	69.2	0.331	-0.169	--	--
Production, Rest of Nation	Original	5,402	--	--	-921	--	-16.7	0.105	--	.31	12.3
	Final	-2,440	--	--	-921	--	63.7	0.105	--	--	--
Mine Stocks	Final	--	19,872	18,209	13,689	12,020	--	--	--	.46	24.0
Furnace Stocks	Final	--	36,562	40,174	52,903	54,433	--	--	--	.53	31.7
Dock Stocks	Final	--	3,154	2,950	3,850	4,185	--	--	--	.09	2.7

1/ The original equations are based on quarterly time series for the 88 quarter period from 1957 to 1978. The final equations are adjusted to the projected annual production levels supplied by the U.S. Bureau of Mines, (Table D.3), for the period from 1978 to 2000. Due to the assumption that stock levels stay constant on an annual basis, the original stock equations did not require adjustment.

U.S. consumption during the previous quarter can be used to accurately determine current domestic production of ore as long as consumption levels stay almost constant and the mix of ore sources does not change rapidly. In effect, if neither the U.S. consumption level nor the proportion of this total supplied by a specific region has changed more than a few percent in the last quarter, a close estimation of the present production level in any region can be made. The equation predicts that a region's production during any given quarter is equal to a percentage of the previous quarter's U.S. consumption. This relationship was statistically significant of the 1% level for both production series once predictable seasonality and trend variation were removed.

The two lagged variables incorporating recent changes in production levels were included in order to allow the changes in production levels between last quarter and the same quarter a year earlier to affect the planning of current production levels. These variables show the impact of recent changes in production levels in Minnesota and the rest of the Nation upon current production levels in these same regions. The model allows the prediction made by viewing last quarter's consumption to be adjusted to the extent that changes in the previous year's production levels affect current production levels. Once the effects of the previous quarter's output demanded, the trend effect, and seasonality were removed from the two production equations, the only variable statistically significant at the 5% level was "change in production in Minnesota". This variable only had a significant impact on its own region.

Dummy variables were introduced in order to account for the effect of seasonality on production. As with the other variables, a seasonal effect had to be significant at the 5% level. Climate apparently has had large effects on Minnesota's production levels. Not only has the average seasonal variation ranged over 10 million long tons between the third quarter and the first quarter, but these effects show statistical significant at the 1% level. Contrary to the extensive seasonality displayed by Minnesota's iron mining industry, other domestic producers have kept their production levels nearly constant throughout any given year. (This refers to the sum of all other domestic producers, not any one of the many regions.) The only quarter that proved itself statistically different from Quarter I for the rest of the nation's production was Quarter III. Even though the significance was at the 1% level, the Quarter III deviation amounted to only a 0.9 million long ton per quarter drop from the otherwise constant seasonal index.

The data show that the production levels in Minnesota and the rest of the U.S. are counter cyclical. This is beneficial since the production pattern of Minnesota, the largest single supplier, is much more seasonal than the U.S. Demand. The shift to taconite production has helped to reduce the seasonality associated with ore production. But, the shipping season has remained subject to climate. As a result, most of the adjustment between quarterly production and consumption is still accomplished by stock management.

In order to use these equations to project future production levels, quarterly values of Minnesota and U.S. production were needed for the years 1976 and 1977. The actual values deviated from the predicted values obtained from the original regression equations. This was most likely due to the 1977 strike, and business cycle fluctuations. Hence, the predicted values from the latter source were used. These are listed in Table D.6.

Table D.6

Predicted Quarterly Iron Ore Production Levels for Minnesota and the Rest of the Nation, 1976 and 1977.

Year	Quarter	Minnesota Production	Rest of Nation Production
		(thousands of long tons)	
1976	I	6,870	6,861
1976	II	15,593	7,050
1976	III	18,356	6,395
1976	IV	10,913	7,321
1977	I	5,578	6,577
1977	II	15,153	6,867
1977	III	18,005	6,284
1977	IV	10,172	6,607

The trend term is used to adjust the equations fitted from past data to the U.S. Bureau of Mines projected production levels. The original historical equations were applied to the values listed in Table D.6. This generated production level projections for the 1978-2000 period. In order to compare the quarterly levels projected by the model to the projections supplied by the U.S. Bureau of Mines, it was necessary to seasonalize the U.S. Bureau of Mine's annual control totals. This was accomplished by performing the following regression on the quarterly historical production series for both Minnesota and the rest of the nation.

$$\frac{PROD_{rqy}}{\sum_{q=1}^{4} PROD_{rqy}} \text{, with } D_i, \qquad \text{Eq. (D.3)}$$

where $PROD_{rqy}$ = the production (in thousands of long tons) in region r during quarter q of year y

D_i = a dummy variable (when q=i, D_q=1.0; when q≠i, D_q = 0.0)

This method first determined, on an annual basis, the portion of the total annual production contributed by each quarter. Next, quarterly contributions for each quarter were averaged for the 1957 to 1978 period. The regression of these terms against the dummy variables determined the average percentage contribution the four quarters made to annual production in each of the two U.S. regions. The results are listed in Table D.7. The application of this distribution yielded a quarterly version of the U.S. Bureau of Mines' annual projections.

Table D.7

Four Quarter Distribution of Domestic Production of Iron Ore in the U.S., by Region, 1957-1978.

Quarter	Minnesota	Rest of Nation
	(percent)	
I (Jan. - Mar.)	13.14	25.34
II (Apr. - June)	32.59	26.73
III (July - Sept.)	35.83	23.43
IV (Oct. - Dec.)	18.44	25.51
Total	100.00	100.00

In order to calibrate the historical equations, correction series were derived. This was done by subtracting the results of the two production equations from the seasonally adjusted U.S. Bureau of Mines control totals. Regression of these correction series with the trend variable t were performed, providing a correction equation with both a constant and a coefficient for the trend term. This allowed manipulation of both the intercept and the slope terms of the original historical equations. By lowering the correction terms by factors of 0.668 and 0.784 for Minnesota and the rest of the nation respectively the final equations were able to arrive at the year 2000 production figures supplied by the U.S. Bureau of Mines. The final production equations are also listed in Table D.5.

U.S. Stocks of Iron Ore

As noted earlier, there are three major classifications of stocks in the iron ore industry: mine stocks, dock stocks, and furnace stocks. The end of quarter levels of these stocks during the 1955-1978 period are listed in Table D.1.2 while the average end of quarter levels are shown in Table D.8.

Mine stocks are stocks stored at minesites prior to shipment to steel mills. These stocks are most significant for the mines located along the shores of Lake Superior. Virtually all of Minnesota's ore is shipped from ports along the eastern end of Lake Superior to steel

Table D.8

Average End of Quarter Level of Iron Ore Stocks at Specified Locations in the U.S., 1955-1978.

Location	Quarter I	II	III	IV
	(thousands of long tons)			
Mine	19,872	18,209	13,689	12,020
Furnace	36,562	40,174	52,903	54,433
Dock	3,154	2,950	3,850	4,185
Total	59,588	61,333	70,442	70,638
Deviation from Previous Quarter	11,050	-1,745	-9,109	-196

mills located along the lower part of Lake Michigan, Lake Ontario, and Lake Erie. Much of the domestically produced ore mined outside Minnesota comes from communities in northern Wisconsin or the Upper Peninsula of Michigan. In addition, a substantial portion of U.S. imports come from the Canadian side of Lake Superior. As with Minnesota's ore, these ores are also shipped through the Great Lakes. During the coldest part of the winter many parts of the Great Lakes freeze over. Even though the shipping season has been extended during recent years by icebreaking, boat transport is still cumbersome, if not impossible, during extremely cold weather. For this reason, a considerable amount of ore is stockpiled during the first quarter, then subsequently shipped to furnaces when the shipping lanes thaw. During the 1957 to 1978 period, U.S. mine stocks averaged 7.85 million long tons higher at the end of Quarter I than they were at the end of Quarter IV. Quarter III was the time when these stocks were depleted most. Quarters II and IV were also times when mine stock levels were reduced. Mine stocks would have fluctuated even more dramatically were it not for the fact that the seasonal patterns in iron ore production levels in Minnesota (and other areas surrounding Lake Superior) have the same basic pattern as the shipping season. The peak production period coincides with the height of the shipping season, thereby helping to keep the amount of storage space needed at minesites lower.

Dock stocks are by far the smallest of the three categories. They fluctuated in a relatively random manner between 1957 and 1978. When tested for seasonality, variation was both low in magnitude and significance level. The annual peaks and troughs usually occurred during Quarters IV and II respectively. Total dock stocks rose slightly when shipping was impossible. Yet, an increase in dock stocks near minesites tended to be coupled with a decrease in dock stocks near furnaces. For this reason docks at transshipment points functioned primarily as short-term storage facilities.

On the average, furnace stocks contained over twice as much ore as mine stocks and dock stocks combined (see Table D.8). As noted earlier, steel producers face a demand which is less seasonal than domestic iron ore production. Therefore, large amounts of ore are stockpiled near the furnaces to ensure an adequate monthly supply. Since the demand for steel usually reaches its highest point puring Quarters I and II, the production and shipment trough, furnace stocks reach their annual low at this time. During the third quarter much of the ore produced during the first two quarters is shipped. But, at this time the demand for steel is almost at its annual low. This explains why an average of about 12.7 million long tons was added to furnace stocks during the third quarter of the years 1957 to 1978.

An additional reason for keeping furnace stocks high is the threat of strikes. As long as furnace stocks are kept high the steel industry will be able to wait out a strike in the iron ore mining industry without significantly altering production plans. Even at the end of the first quarter, furnace stocks averaged over 36.5 million long tons during the years between 1957 and 1978. Compared to the average demand for iron ore during the 1957 to 1978 period, 116.1 million long tons per year, furnace stocks alone would last longer than a quarter, even if all mines were completely shut down. Within this length of time, steel mills could adjust their import levels to satisfy their supply requirements.

Another explanation for strikes may be that mining companies are in a stronger negotiating position relative to their labor unions when the demand for ore is low and the stockpiles are high. This occurs because recessions bring about a reduced demand for steel. As a result, iron ore stocks tend to build up beyond the usual levels. The entries in Table D.1 show that during the 1975-76 recession 10.45 and 6.92 million long tons of ore were added to stockpiles in 1975 and 1976 respectively. Yet, consumption during these two years averaged about 19.8 million tons per year less than during the 1973-74 period. During the end of 1977, primarily in Quarters III and IV, a strike took place, allowing stocks to be reduced by over 15.6 million long tons that year. A similar pattern occurred right before and during the strike in the late 1950's. During times of high GNP growth mining firms are better off to accept any reasonable contract than risk losing sales. Although the timing of strikes in this manner has a destabilizing effect on the economy as a whole, it provides an inventory-clearing mechanism for the iron mining and steel producing industry.

An assumption made by the U.S. Bureau of Mines is that over the long run total stocks remain constant. This is a reasonable assumption as long as production and consumption levels stay almost constant. Although stocks varied greatly from year to year during the 1957 to 1978 time period, the net change over the 22 year period was a net stock level increase of just under 4.6 million long tons. The average annual consumption level during the first five years of the series was 111.9 million long tons, or 3.6 million long tons less than the average annual consumption level of 115.5 million long tons during the last five years of the series. Whether or not the increase in U.S. consumption to 185.1 million long tons per year by 2000 will cause an upward or downward scaling of stocks, particularly mine and furnace stocks, is uncertain. But, for the purposes of the first model, quarterly stock levels were assumed to stay at the levels listed in Table D.8 for the 1978 to 2000 period. Stock levels fluctuate in a predetermined fashion on a quarterly basis but remain constant over the period of a calendar year.

The extent to which stocks contribute to quarterly U.S. consumption can be shown indirectly from Table D.8. The average total stocks in the U.S. during any quarter equals the sum of the levels of the three components. The contribution of stocks to consumption during any quarter is equal to the difference between previous quarter's total and the present quarter's total. For example, on the average, by the end of Quarter IV, total stocks averaged 70,638 thousand long tons. By the end of Quarter I they averaged only 59,588 thousand long tons. This indicates that, on the average, during the first quarter of the years 1957 to 1978, 11,050 (70,638-59,588) thousand long tons of the nation's stocks were consumed, hence boosting the effective iron ore supply during this quarter by this amount.

U.S. Imports of Iron Ore

Imports are the most feasible residual in the model. If U.S. iron ore demand can be supplied domestically at a competitive price there is little reason to continue importing. On an annual basis, the assumption of fixed stock levels determines import levels to be the difference between domestic consumption and domestic production. In the shorter run, quarterly seasonality in the levels of consumption, domestic production and the three types of stocks will have tremendous impacts upon import levels.

Summary

Projected domestic consumption and the three sources of total projected U.S. iron ore supply -- domestic production, stocks and imports -- are summarized on annual and quarterly basis for the 1978-2000 period in Tables D.4 and A.3. The projected levels are based on historical relationships and, hence, they represent the interregional and interindustry relationships which prevailed up to 1978. These relationships are changing but to the extent these changes are included in the forecast models, for example, in the values of the t variable, the projected quarterly production levels incorporate these changes.

Expanding the Simple Forecasting Model: Model II

The construction of the time trend variable, t, used in the previously discussed model, is restrictive to the extent that the four seasons are forced to relate to a quarterly trend. The trend term for any quarter exceeds the previous quarter by one. As a result, the later quarters in any given year will consistently be affected more by the trend effect than the early quarters. In addition, seasonality is not able to vary as time proceeds because quarterly effects are fixed.

A more flexible system of trend terms was created by setting a new term T equal to the quantity (Year-1956). Next, a series of matrices, (one for each year), containing dummy variables was constructed. Each annual 4 by 4 matrix, A_T, was obtained by multiplying a scalar of magnitude T by a 4 by 4 identity matrix.

$$A_T = T^* \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} T & 0 & 0 & 0 \\ 0 & T & 0 & 0 \\ 0 & 0 & T & 0 \\ 0 & 0 & 0 & T \end{bmatrix} \qquad \text{Eq. (D.4)}$$

For example, the matrix corresponding to 1970 was found by setting T equal to 1970-1956 = 14. Hence,

$$A_{14} = \begin{bmatrix} 14 & 0 & 0 & 0 \\ 0 & 14 & 0 & 0 \\ 0 & 0 & 14 & 0 \\ 0 & 0 & 0 & 14 \end{bmatrix} \qquad \text{Eq. (D.5)}$$

This formulation of the trend term helps solve both the forementioned deficiencies. Within every year, the value of the trend term is constant. And more importantly, seasonal variation need not be held constant. The seasonal pattern in a dependent variable is allowed to vary with time. Although natural ore mining is influenced greatly by climate, taconite ore mining and processing is not nearly as seasonal in nature. As Minnesota and other producing regions have moved from natural ore to taconite ore production, the seasonal relationships between production, stocks, and imports have undergone change. To better represent these structural changes, an expanded version of the initial forecasting model was constructed.

In constructing Model II it was assumed that the independent variables which were statistically significant in Model I would remain so. Aside from the expansion of the trend term, dummy variables allowing for intercept differences were added to the list of independent variables. This was done in order to facilitate initial seasonal patterns in all dependent variables. The coefficients of the multiple regressions are tabulated in Tabld D.9. None of the dummy variables were removed from any equation, no matter how low their siggificance level. This

Table D.9

Historical Iron Ore and Taconite Production, Stock and Import Equations: Model II. 1/

	Constant Term 2/	Dummy Variable-Intercepts Second Qtr.	Third Qtr.	Fourth Qtr.	Dummy Variable - Slopes First Qtr.	Second Qtr.	Third Qtr.	Fourth Qtr.	Output Demanded Lagged 1	Change in Minnesota Production Lagged 1,5	Change in Rest of Nation Production Lagged 1,5	Relevant Statistics R^2	Overall F
Production, Minnesota	-5,055 (2,203)	14,883 (1,973)	18,387 (2,011)	6,045 (1,925)	346 (106)	-188 (104)	-350 (104)	62 (108)	.285 (.074)	-.126 (.080)		.77	29.3
Production, Rest of Nation	5,673 (703)	-307 (677)	-1,612 (681)	-246 (662)	-82 (36)	-57 (36)	-35 (36)	-93 (37)	.107 (.022)			.33	4.9
Mine Stocks	16,557 (1,814)	-382 (1,747)	-3,344 (1,759)	-5,023 (1,710)	489 (93)	407 (92)	281 (92)	250 (95)	-.088 (.058)			.70	22.8
Furnace Stocks	57,232 (3,747)	9,903 (3,308)	27,369 (3,367)	22,826 (3,223)	-146 (177)	-456 (173)	-798 (174)	-552 (182)	-.705 (.126)	-.297 (.186)	2.543 (.664)	.80	30.0
Dock Stocks	9,161 (776)	613 (692)	2,455 (701)	801 (675)	-97 (37)	-110 (36)	-170 (36)	-68 (38)	-.183 (.026)		.346 (.100)	.64	15.2
U.S. Imports	54 (1,206)	1,630 (1,080)	1,763 (1,101)	2,909 (1,053)	-31 (58)	98 (57)	218 (57)	75 (59)	.209 (.040)	-.136 (.044)		.71	21.3

1/ The standard deviation associated with each coefficient is entered below it in brackets.
2/ The quarter I intercept is included in the constant term.

ensure that each quarter has seasonal terms for both the slope and the intercept. Invariably the coefficients with low statistical significance levels were also low in magnitude.

Seasonal Trends in Production

The regression coefficients show that Minnesota's iron ore industry is becoming less dependent on climatic conditions. Initially, much higher production levels were recorded in Quarters II and III than in Quarters I and IV. However, the higher the value of a quarter's initial intercept coefficient, the smaller the value of the same quarter's slope coefficient was. This indicates that Minnesota's production levels are evening out with time. The same is true of the Rest-of-Nation production levels. The quarters which had highest initial intercepts had the most negative slope coefficients.

When Minnesota's production equation was projected to the year 2000 the results did not approximate the control totals supplied by the U.S. Bureau of Mines. The seasonally related trend coefficients based on historical data were too large. The trend terms were appropriate only for the 1955 to 1978 period, an era in which natural ore production declined from 99 percent of total production in 1955, to 9 percent in 1978. Such a trend could obviously not continue at this pace until the year 2000. For this reason, the large trend terms were deflated substantially. This was completed by multiplying each trend term by 0.65. In this way, production levels slowly lost their seasonality. This dampening effect was so gradual that by the year 2000 Quarter I and IV production levels were projected to be only slightly below those of Quarters II and III. The trend term coefficients for the rest of the nation did not need calibration.

On an annual basis, neither Minnesota nor the Rest-of-Nation production rose to the levels listed in Table D.3. This occurred because neither type of domestic production rose dramatically during the historical period. Both equations were adjusted to the control totals supplied by the U.S. Bureau of Mines. This was done in two steps. First, a constant was added to the 1978 value projected by the unadjusted model, thus setting it equal to the U.S. Bureau of Mines projection for that year. One fourth of this annual figure was added to each quarterly value determined by the production equations. Then, the remaining deviation for the year 2000 was split into eighty-eight parts. For each quarter after 1978, one part was added to the projected trendline. In essence, the two correction terms needed to be added to their respective production equations in order to make the annual results approximate those projected by the U.S. Bureau of Mines are derived as follows:

Minnesota Production: $$\frac{5{,}500}{4} + \frac{27{,}900}{4*22}\,(\text{Year} - 1978) \qquad \text{Eq. (D.6)}$$

Rest of Nation Production: $$\frac{-1{,}000}{4} + \frac{25{,}600}{4*22}\,(\text{Year} - 1978) \qquad \text{Eq. (D.7)}$$

Table D.10

Projected Annual Consumption and Supply of Iron Ore and Related Employment, U.S. and Minnesota, 1978-2000: Model II.[1/]

Year	Consumption	Change in Stocks	Imports	Domestic Production			Minnesota Employment	
				Total	Minnesota	Rest of Nation	Econometric Forecast	Technological Forecast
1978	131694.	-4.	45629.	86069.	58593.	27476.	12751.	13507.
1979	134478.	10.	43940.	90528.	61595.	28933.	12895.	13557.
1980	137346.	20.	43348.	93979.	63842.	30136.	12982.	13416.
1981	139646.	29.	42556.	97061.	65767.	31295.	13043.	13194.
1982	142007.	38.	41891.	100078.	67634.	32445.	13099.	12955.
1983	144430.	47.	41276.	103107.	69506.	33601.	13152.	12711.
1984	146915.	56.	40701.	106158.	71394.	34763.	13205.	12466.
1985	149461.	65.	40164.	109232.	73299.	35933.	13257.	12203.
1986	151745.	74.	39432.	112239.	75156.	37083.	13306.	11930.
1987	154080.	82.	38762.	115236.	77007.	38229.	13352.	11655.
1988	156468.	91.	38127.	118250.	78868.	39382.	13398.	11381.
1989	158909.	99.	37524.	121286.	80745.	40541.	13444.	11110.
1990	161403.	108.	36955.	124340.	82635.	41705.	13489.	10824.
1991	163579.	116.	36153.	127311.	84467.	42844.	13531.	10533.
1992	165798.	124.	35411.	130264.	86285.	43978.	13571.	10244.
1993	168061.	131.	34700.	133230.	88112.	45118.	13611.	9959.
1994	170367.	139.	34015.	136213.	89950.	46263.	13650.	9679.
1995	172716.	147.	33357.	139212.	91801.	47411.	13689.	9387.
1996	175110.	155.	32726.	142229.	93664.	48565.	13729.	9101.
1997	177548.	163.	32122.	145263.	95540.	49723.	13768.	8822.
1998	180030.	171.	31546.	148314.	97428.	50886.	13807.	8549.
1999	182558.	179.	30996.	151383.	99330.	52054.	13845.	8283.
2000	185132.	187.	30474.	154471.	101245.	53227.	13884.	8023.

1/ Consumption and production are measured in thousands of long tons; employment is measured in thousands.

The final production runs are listed in Tables D.10 and A.4.

Seasonal Trends in Stocks

Production levels become less seasonally volatile as taconite ore replaces natural ores. The shipping season has been extended, but only slightly so. As a result, the relative increase in production during the first and the fourth quarters will result in an increased need for storage at the minesites and at Lake Superior docks. Shipping during the ice-free quarters must increase to accomodate increasing production levels. The minestock equation supports this reasoning. Quarter I, and to some extent Quarter II, have much larger trend terms than the other two quarters. During Quarter I few ships move, while Quarter II is a starting quarter in which ships must attempt to move both the stocks from the previous quarter and concurrently produced ore.

Although dock stocks are decreasing slightly, stocks at the furnaces are decreasing much more rapidly. In addition, the equations indicate that furnace stocks are quickly losing their strongly seasonal pattern. The institutionalized storage of large quantities of stocks near furnaces. is expensive. One must consider not only storage costs but the opportunity costs of large inventories. These costs could be reduced by lowering stock levels.

The trend terms also affected stock level forecasts to a dramatic extent. In order to curb divergence yet preserve the characteristics of the equations, all the stock projections were averaged with past values. The average level of each type of stock was computed on a quarterly basis for the 1974 to 1978 period. These values are listed in Table D.11.

Table D.11

Average Quarterly Stock Levels, 1974-1978.

Quarter	Mine Stocks	Furnace Stocks	Dock Stocks
		(thousands of long tons)	
1	20,796	33,747	2,702
2	18,879	36,169	2,872
3	13,979	44,584	3,357
4	12,209	47,059	3,839

The assumption was that the value obtained by averaging over the given five-year period provided a better starting point for the stock projection series than the actual 1978 values. Subsequently, stock projections were made one quarter at a time. After each calculation, the projection given by Table D.9 was given a weight of 0.01 (1 percent), while the value during the same quarter the previous year was given a weight of 0.99 (99 percent). In this way all three stock levels kept their original trend, but to a much lesser extent than indicated in the original equations. The adjusted run is listed in Table A.5. The net annual decrease in the total domestic stock level is included in Table D.11.

Seasonal Trends in Imports

As in Model I, imports were set equal to consumption, less domestic production and changes in stock levels. The consumption values used were those derived by Model I. The implicit assumption is that seasonal pattern in ore consumption will not change between now and the year 2000. Consumption is relatively independent of climate, but grows steadily, hence the trend term of Model I is appropriate. Projections of the net depletion of stocks, during any quarter,in essence the net contribution of stocks to current consumption, wre derived by subtracting the given quarter's total stock level from the previous quarter's total stock level. Both measurements are taken at the end of the relevant quarters. The resulting import figures are listed along with consumption, production, and change in stock figures in Table D.11 and A.4. Although imports were viewed as residuals, a regression was performed on past import levels. This equation is also listed in Table D.9. From the large positive coefficients it is evident that imports rose during the 1957 to 1978 period from which the equation was derived. The U.S. Bureau of Mines, however, predicts that import levels will decline from their all time highs in the early 1970's, and eventually level off at approximately 30.6 million long tons per year by the late 1990's. It is clear that the historical import equation's projections would imply steady import growth, thus contradicting the U.S. Bureau of Mines' projections.

Forecasting Minnesota Employment

Employment projections for Minnesota's iron mining industry may be derived from Minnesota production levels. Two distinct methods were applied. The results of both are listed in Tables D.10 and A.4.

Econometric Forecasting Method

This method was performed by regressing quarterly employment levels against the base-ten logarithm of state production, and both constant and trend term dummy variables. This procedure resulted in the following equation:

$$EMPS_{yq} = 10^{.21863} * PRODS_{yq}^{.30424} * 10^{XC_q} * T^{XT_q} \qquad \text{Eq. (D.8)}$$

where,

- $EMPS_{yq}$ = Minnesota employment during year y and quarter q;
- $PRODS_{yq}$ = Minnesota production during year y and quarter q;
- T = number of years starting from 1956, with T=Year-1956;
- XC_q = the exponent for the constant seasonality index during quarter q;
- XT_q = the exponent for the seasonality index that varies with time during quarter q.

This equation has a R^2 of 0.71 and an overall F test of 24.5. The values of XC_q for the four quarters are listed below in Table D.12.

Table D.12

Values of Dummy Variable Constants for Minnesota Employment Regression

Quarter	XC_q	XT_q
I	0.000	-0.278
II	-0.279	-0.081
III	-0.305	-0.064
IV	-0.199	-0.113

The exponent of state production is positive, indicating that increasing employment may be identified with rising production levels. Yet, the coefficient is considerably below one, indicating a less than proportional relationship. Labor, as an input to the production process, decreases in relation to other inputs as capacity is increased. A doubling of production is associated with only a 30 percent increase in employment. The negative seasonal trend term exponents further deflate the employment projections. These terms project future increases in productivity associated with technological change. When viewed together, it can be seen that the XC_q and XT_q terms reduce seasonal fluctuations in employment. For example, Quarter I has the largest XC_q term and the lowest XT_q term. The decrease in seasonality of the production series also has a dampening effect upon the seasonality of the employment series.

Even though all the trend terms in the model have the effect of reducing the employment levels associated with future production increases, the forecast equation still shows employment levels increasing gradually throughout the rest of this century. Production is projected to rise fast enough to offset the effects of negative trend terms. During the historical period over which the data were regressed, large costs were incurred in converting the Minnesota iron mining industry from one based primarily on natural ores to one based almost exclusively on taconite. This industry-wide reorganization resulted in substantial, but temporary, decreases in productivity. If productivity does not rise as quickly as production levels, employment must rise. Now that the industry has been almost totally converted to taconite mining, it is unlikely that future productivity increases will remain low. This adjustment is incorporated in the second method for projecting employment levels.

Technological Forecasting Method

In the technological forecast method, annual employment levels are derived as an indirect result of the projections of both annual production and future worker productivity. Table D.13 shows the projected annual rates of increase in worker productivity for the 1978 to 2000 period in the baseline and adjusted forecast series. The adjusted forecast series assume approximately a 13 percent lower rate of increase in productivity than in the baseline forecasts.

Table D.13

Projected Annual Rates of Increase in Worker Productivity in Minnesota's Iron Mining Industry, 1978-2000.[1/]

Time Period	Annual Rate of Increase (%)	
	Baseline	Adjusted
1978-1984	4.74	3.68
1985-1989	4.88	4.26
1990-1994	5.04	4.40
1995-2000	5.23	4.57

1/ These rates were obtained from SIMLAB (5).

The employment for each year is obtained from the following formula:

$$EMPS_y = PRODS_y * \left(\frac{PRODS_{y-1}}{EMPS_{y-1}} * R_y \right)^{-1} \quad \text{Eq. (D.9)}$$

where, $EMPS_y$ = Minnesota's average annual employment in year y;

$PRODS_y$ = Minnesota's total iron ore production in year y;

R_y = the annual rate of increase in worker productivity applicable for year y;

$\frac{PRODS_{y-1}}{EMPS_{y-1}}$ = productivity during year y-1.

Employment in year y was found by first raising the previous year's productivity by the factor Table D.12 indicates as appropriate for year y, then multiplying production in y by the inverse of the productivity ratio projected for year y. Contrary to the conclusion of Method I this method projects employment levels to decrease throughout the remainder of the century.

In order to introduce seasonality into the technological forecast's annual employment projections, seasonal patterns in Minnesota's iron mining employment between 1957 and 1978 were compared to the seasonal patterns observed in Minnesota's production levels during the same period. Table D.13 compares Minnesota's average quarterly employment and production levels. Quarterly values are shown as percentages of annual averages.

Table D.14

Average Quarterly Employment and Production in Minnesota as a Percentage of Annual Averages, 1957 to 1978.

Quarter	Employment		Production	
	Percentage of Annual Average	Absolute Deviation	Percentage of Annual Average	Absolute Deviation
		(percent)		
1	94.46	5.54 (-)	79.48	20.52 (-)
2	103.58	3.58 (+)	122.20	22.20 (+)
3	104.59	4.59 (+)	144.52	44.52 (+)
4	97.37	2.63 (-)	83.80	16.20 (-)
Total	400.00	16.34	400.00	133.44

In order to obtain these figures, all quarterly employment and production levels were divided by the annual total to which they contributed. The two series were then multiplied by four to obtain estimates of average quarterly values at seasonally adjusted annual rates. These series were subsequently regressed against constant dummy variables in order to derive the average seasonal coefficients. It is clear from the results that production levels have been much more volatile than employment levels during the 1957 to 1978 period. Within the seasonality range observed, a change in production by 10 percent was associated with an average employment change of only 1.2 percent (i.e., $10.0 * \frac{16.34}{133.44}$). Once all four quarterly Minnesota production values had been projected for year y, quarterly employment was computed by Equation D.10.

$$EMPS_{yq} = EMPS_{y} * \left[1.0 - \frac{16.34}{133.44} \left(1.0 - \frac{PRODS_{yq} * 4}{PRODS_{y}}\right)\right] \qquad \text{Eq. (D.10).}$$

where, $EMPS_{yq}$ = Minnesota's iron mining employment in year y, quarter q;

$EMPS_{y}$ = Minnesota's average annual iron mining employment in year y;

$PRODS_{yq}$ = Minnesota's iron ore production during year y, quarter q;

$PRODS_{y}$ = Minnesota's iron ore production during year y.

The technological forecast method yields forecasts of Minnesota iron mining employment levels which decline (both the baseline and adjusted forecast series), even if production levels rise at the rate projected by the U.S. Bureau of Mines. Assuming that the low productivity levels experienced during the 1957 to 1978 period were only temporary, decreasing employment levels are to be expected. This is an important conclusion since Northeast Minnesota's economy relies upon iron mining as its largest basic industry.

Summary and Conclusions

The main purpose of this report is to assess the principal sources of seasonal and regional variability in iron ore production in Minnesota and the U.S. and to project future production and employment levels in this industry. Of particular interest in the preparation of this report were the levels of iron ore production, stocks and imports, as well as the related employment, and their relationships to the general level of economic activity in the United States.

Prior to World War II, only high grade goethite and hemitite ores, usually termed 'natural ores', were utilized as steel mill feedstock. But, the war effort brought about rapid depletion of the economically accessible natural ores in Minnesota and the rest of the nation. As a result, U.S. iron ore imports escalated rapidly during the first several post-war years.

During the early 1920's researchers at the University of Minnesota's Minerals Research Center discovered a method enabling the steel industry to utilize low grade taconite ores. Due to economic and availability criteria, taconite has steadily replaced natural ores as a source of raw iron since that time. Before 1955 taconite accounted for less than 1% of U.S. iron ore production. By 1978 taconite production accounted for approximately 92% of the total.

Overall taconite ores are chemically superior to natural ores. Although the energy and initial capital costs of primary treatment near minesites are higher, the increased energetic efficiency in blast furnaces more than compensates for the higher initial costs. Taconite is a hard, rock-resembling ore. Blasting is needed to free it from the earth. Thereafter it is processed for shipping. This can be carried out effectively independent of climate. In contrast, natural ores resemble clay in that they are soft and contain large quantities of water. These ores are extremely difficult to excavate when the contained water freezes. As a result, natural ore production during summer months is several times the level observed during the winter.

The virtual elimination of seasonality from production levels accomplished by the switch to taconite ore has brought about other industry adjustments as well. The cheapest way to move ore to the steel mills has been through the Upper Great Lakes by ship. Yet, the length of the shipping season is inherently dictated by climate. When natural ore production prevailed, the production and shipping seasons coincided, hence minimizing the need for stock storage at minesites and nearby lakeside docks. The move to taconite increased the need for these storage facilities during winter months. Future taconite production increases will further increase such demands.

Throughout the shift to taconite production furnace stocks were maintained at levels high enough to meet more than a half-years supply requirement. These stocks provided an essential buffer between the steel industry and the level of activity in the economy. Cyclical fluctuations could be absorbed by furnace stocks in the short run. If a business cycle persisted, steel producers had time to adjust domestic production and import levels.

Regression analysis of the historical data series for the U.S. iron mining industry indicated that furnace stock levels may actually decline in the years to come. This may result from more effective moderation of the effects of business cycles on iron and steel production, less seasonality in the stock transfer system (increased relative importance of taconite and extension of the shipping season by icebreaking), and the recycling of iron and steel products.

A potential flaw in the iron ore industry projections to 2000 results from the fact that total domestic production of iron ore rose only slightly between 1955 and 1978. The U.S. Bureau of Mines expects U.S. production to undergo a dramatic rise from 80.7 million long tons in 1978, to 154.5 million long tons by the year 2000. This rise will represent a break with the trend observed during the 1955-1978 period. Furnace stock levels depend on production levels. Hence, projections based on historical data may underestimate the required levels of furnace stocks. The reduced seasonality in production will not free the industry from its traditional sensitivity to business cycle flucutations, which implies that stocks will still serve as buffers between the industry and the level of economic activity.

Employment levels will not rise along with production increases if the projected annual productivity increases are assumed(see Table D.3). The Minnesota iron ore industry employment levels experienced between 1955 and 1978 were maintained partially due to the industry-wide shift from natural ores to taconite. Presently, most of the industry has undergone the technological change. For this reason, productivity will be more likely to rise in the next two decades. The increased productivity will exert a downward pressure on the employment level. Rises in productivity per worker will be slowed if energy shortages continue.

The effect of the switch from a natural ores based industry to an industry based on taconite has been to reduce seasonality in employment levels. Throughout the 1955 to 1978 historical period, employment levels varied seasonally, but were more stable than production levels. By switching feedstocks, the climate's influence on employment is virtually eliminated. In effect, Northeast Minnesota's iron mining industry has been changed from a summer-boom, winter-bust type activity to a more stable manufacturing process. It is important to note that business cycles will continue to cause fluctuations in the demand for iron ore and hence, labor. But, at least one source of layoffs has been eliminated.

Increased iron ore production will require extensive capital expansion in Northeast Minnesota. Taconite processing is much more energy intensive than natural ore excavation. Thus, the capacity of natural gas and electricity providing networks will also need expansion. Since steelmaking is a weight-losing process, it may be advantageous to consider location of steel mills closer to the raw material sources. However, an analysis of the impacts of such a development on Northeast Minnesota and the rest of the Nation is outside the scope of this report.

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Appendix D.1: Selected Quarterly Tables

Table D.1.1

Estimated Quarterly Consumption and Supply of Iron Ore in the U.S., by Source, 1955-1978.

Year and Quarter		Consumption[1]	Net Change in Stocks[2]	Total Supply[1]	Net Imports[2]	Domestic Production Total[2]	Domestic Production Minnesota[3]	Rest of Nation	Iron Mining Employment U.S.[4]	Iron Mining Employment Minnesota[5]
1955.	1.	29950.	16935.	12015.	3260.	8755.	1067.	7686.	30370.	12930.
1955.	2.	34392.	-2943.	37335.	5755.	31580.	22091.	9489.	33770.	15400.
1955.	3.	34137.	-14774.	48911.	7287.	41624.	31627.	9997.	36800.	17590.
1955.	4.	33153.	2974.	30179.	6565.	23614.	13959.	9655.	35100.	16870.
1956.	1.	31499.	16638.	14861.	4341.	10520.	1641.	8879.	35470.	16490.
1956.	2.	34588.	-7369.	41957.	7670.	34287.	24074.	10213.	37700.	19530.
1956.	3.	25473.	-9635.	35108.	10252.	24856.	17832.	7019.	29370.	15070.
1956.	4.	32855.	-2278.	35133.	8093.	27040.	17108.	9932.	37770.	18030.
1957.	1.	33638.	18011.	15627.	4508.	11119.	2243.	8876.	36270.	17500.
1957.	2.	36030.	-6288.	42318.	8614.	33704.	23831.	9873.	39700.	19300.
1957.	3.	36899.	-16901.	53800.	12194.	41606.	31461.	10145.	42070.	20570.
1957.	4.	11992.	-14188.	26180.	6611.	19569.	10563.	9006.	39600.	18630.
1958.	1.	21356.	7274.	14082.	4644.	9438.	2505.	6933.	33570.	16100.
1958.	2.	20773.	-1933.	22706.	6152.	16554.	10238.	6316.	30190.	14030.
1958.	3.	21509.	-11730.	33239.	6660.	26579.	20154.	6275.	31670.	16530.
1958.	4.	30137.	3615.	26522.	10926.	15596.	8503.	7093.	31910.	15770.
1959.	1.	32599.	16547.	16052.	5182.	10870.	3217.	7653.	31970.	15170.
1959.	2.	36423.	-2735.	39158.	8451.	30707.	22617.	8090.	35190.	17600.
1959.	3.	4571.	-11479.	16050.	8853.	7197.	4603.	2594.	19130.	9430.
1959.	4.	18328.	-2026.	20354.	10153.	10201.	4764.	5437.	24730.	11530.
1960.	1.	36722.	17263.	19459.	6899.	12560.	4029.	8531.	33230.	15270.
1960.	2.	30441.	-9239.	39680.	8722.	30958.	22675.	8283.	35170.	17170.
1960.	3.	19582.	-18800.	38382.	8316.	30066.	23509.	6557.	33970.	16700.
1960.	4.	19083.	-421.	19504.	5450.	14054.	6587.	7467.	30600.	15270.
1961.	1.	18635.	4123.	14512.	4302.	10210.	3529.	6681.	27370.	13270.
1961.	2.	25311.	2391.	22920.	4185.	18735.	11433.	7302.	26970.	13670.
1961.	3.	25841.	-5684.	31525.	6091.	25434.	18989.	6445.	26690.	14100.
1961.	4.	26769.	3859.	22910.	6281.	16629.	9290.	7340.	26430.	12930.
1962.	1.	31179.	14563.	16616.	5175.	11441.	3795.	7646.	25970.	12070.
1962.	2.	26636.	-5929.	32565.	8877.	23688.	16256.	7432.	26900.	13770.
1962.	3.	19780.	-14740.	34520.	8914.	25606.	19390.	6216.	25530.	14130.
1962.	4.	21236.	3460.	17776.	5896.	11880.	6059.	5821.	22470.	11530.
1963.	1.	25328.	11199.	14129.	3890.	10239.	3991.	6248.	21600.	9330.
1963.	2.	31095.	3026.	28069.	6665.	21404.	13907.	7497.	24430.	11870.
1963.	3.	24746.	-10680.	35426.	9055.	26371.	19295.	7076.	25070.	13100.
1963.	4.	23046.	2083.	20963.	6226.	14737.	7903.	6834.	26530.	11670.
1964.	1.	28536.	11498.	17038.	4716.	12322.	4756.	7566.	22570.	10070.
1964.	2.	30216.	-2800.	33016.	8919.	24097.	15737.	8359.	25070.	12130.
1964.	3.	31920.	-7657.	39577.	12118.	27459.	19438.	8021.	25530.	13200.
1964.	4.	33165.	6035.	27130.	9651.	17479.	8969.	8510.	24670.	11570.
1965.	1.	34511.	14059.	20452.	6987.	13465.	4788.	8677.	24770.	11730.
1965.	2.	35557.	522.	35035.	10320.	24715.	15924.	8791.	26230.	13130.
1965.	3.	32106.	-10448.	42554.	10913.	31641.	22514.	9127.	26970.	14100.
1965.	4.	24976.	-2424.	27400.	9801.	17599.	9275.	8324.	26100.	12900.
1966.	1.	30674.	11900.	18774.	4527.	14247.	5550.	8697.	24990.	12030.
1966.	2.	34149.	-3137.	37286.	9618.	27668.	18219.	9449.	26430.	13600.
1966.	3.	33416.	-9434.	42850.	12551.	30299.	21735.	8564.	27070.	14600.
1966.	4.	29689.	-586.	30275.	11785.	18490.	9497.	8993.	25570.	12770.
1967.	1.	30748.	10689.	20059.	5561.	14498.	5747.	8751.	25030.	12100.
1967.	2.	30552.	-4720.	35272.	10537.	24735.	15742.	8993.	25930.	12670.
1967.	3.	28921.	-10658.	39579.	11481.	28098.	19772.	8326.	26230.	13030.
1967.	4.	31793.	3611.	28182.	11218.	16964.	8440.	8524.	25030.	12500.
1968.	1.	34870.	13829.	21041.	5094.	15947.	7185.	8762.	24770.	12100.
1968.	2.	35449.	-1421.	36870.	11099.	25771.	16918.	8853.	26100.	13500.
1968.	3.	27308.	-12405.	39713.	12042.	27671.	18802.	8869.	26170.	14600.
1968.	4.	24803.	-536.	25339.	9168.	16171.	8995.	7176.	24130.	12900.
1969.	1.	31530.	11649.	19881.	3800.	16081.	7344.	8737.	24490.	12630.
1969.	2.	35282.	2398.	32884.	7573.	25311.	16095.	9215.	25890.	13170.
1969.	3.	31257.	-7921.	39178.	10964.	28214.	20194.	8020.	26570.	14270.
1969.	4.	30823.	-1790.	32613.	12978.	19635.	11266.	8369.	25130.	13030.
1970.	1.	32463.	10647.	21816.	5586.	16230.	8257.	7973.	24690.	12230.
1970.	2.	31768.	-4487.	36255.	10838.	25417.	16691.	8726.	25930.	13570.
1970.	3.	32537.	-9182.	41719.	13787.	27932.	19773.	8159.	26900.	14670.
1970.	4.	29218.	-163.	29381.	9169.	20212.	11479.	8733.	24770.	12730.
1971.	1.	32866.	10590.	22276.	5800.	16476.	8462.	8014.	23630.	11370.
1971.	2.	34054.	-3031.	37085.	12591.	24494.	16393.	8101.	24600.	13230.
1971.	3.	22008.	-13333.	35341.	11268.	24073.	17098.	6975.	24670.	13670.
1971.	4.	22708.	-2452.	25160.	7984.	17176.	9981.	7195.	21870.	12030.
1972.	1.	28784.	9995.	18789.	4567.	14222.	8307.	5915.	19870.	11590.
1972.	2.	32413.	2421.	29992.	8934.	21058.	13597.	7461.	20530.	11570.
1972.	3.	29405.	-3358.	32763.	9791.	22972.	16335.	6637.	21290.	12600.
1972.	4.	30726.	2694.	28032.	10374.	17658.	11053.	6605.	22070.	12570.
1973.	1.	33139.	11695.	21444.	5602.	15842.	9492.	6350.	21770.	11670.
1973.	2.	34646.	-34.	34680.	10707.	23973.	16991.	6982.	23370.	13000.
1973.	3.	33495.	-4990.	38485.	12461.	26024.	19425.	6599.	24130.	13530.
1973.	4.	34055.	844.	33211.	12716.	20495.	13818.	6677.	23600.	12430.
1974.	1.	35528.	12315.	23213.	6821.	16392.	9879.	6513.	23500.	11970.
1974.	2.	34273.	-398.	34671.	11776.	22935.	16415.	6520.	24170.	12870.
1974.	3.	32241.	-6037.	38278.	13822.	24456.	19024.	5432.	24970.	13370.
1974.	4.	30127.	-4095.	34222.	14027.	20195.	14092.	6103.	25070.	13430.
1975.	1.	31292.	4785.	26507.	9730.	16777.	9841.	6936.	24670.	12470.
1975.	2.	30033.	-4717.	34750.	12063.	22687.	15784.	6903.	25370.	13100.
1975.	3.	26639.	-8501.	35140.	11974.	23166.	15791.	7375.	25870.	13270.
1975.	4.	26104.	-2018.	28122.	10396.	17726.	10985.	6741.	24030.	12590.
1976.	1.	28067.	5037.	23030.	6961.	16069.	9273.	6796.	23100.	12170.
1976.	2.	30750.	-1011.	31761.	10185.	21576.	13816.	7760.	23670.	13390.
1976.	3.	30955.	-5244.	36199.	14171.	22028.	14599.	7429.	26570.	14070.
1976.	4.	24049.	-5704.	29753.	11174.	18579.	11494.	7085.	25000.	14670.
1977.	1.	26956.	4986.	21970.	4155.	17815.	10362.	7453.	25500.	13530.
1977.	2.	30332.	1553.	28779.	8295.	20484.	13149.	7335.	26130.	14070.
1977.	3.	24903.	2579.	22324.	11979.	10345.	5735.	4610.	15530.	8130.
1977.	4.	26580.	6633.	19947.	13306.	6641.	2610.	4031.	13530.	9230.
1978.	1.	25523.	6306.	19217.	2468.	16749.	10031.	6718.	23100.	13070.
1978.	2.	27359.	1197.	26162.	4369.	21793.	15136.	6657.	25670.	14790.
1978.	3.	31369.	-2794.	34163.	11177.	22986.	16027.	6959.	25570.	15970.
1978.	4.	26669.	-658.	27327.	7197.	20130.	13834.	6296.	25570.	15570.

1/ Consumption is equal to total supply plus the change in stocks. Total supply is equal to net imports plus total domestic production.
2/ U.S. Department of Commerce, Survey of Current Business, January, 1956-1979, page 532 and April 1979, page 522.
3/ U.S. Department of the Interior, Bureau of Mines, Preliminary Area Reports (Mun. 39) and the Mineral Industry Survey series.
4/ U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings, U.S., 1955-1978.
5/ Minnesota Department of Economic Security, Research and Statistical Services Office.

Table D.1.2

Estimated End of Quarter Stocks of Iron Ore in the U.S., by Location, 1955-1978. 1/

Year & Quarter		Mine	Furnace	Dock	All Locations
		(thousands of long tons)			
1955.	1.	10109.	18616.	5095.	33820.
1955.	2.	9402.	22455.	4906.	36763.
1955.	3.	6130.	38459.	6948.	51537.
1955.	4.	4204.	37539.	6820.	48563.
1956.	1.	3905.	25365.	2655.	31925.
1956.	2.	8459.	27468.	3367.	39294.
1956.	3.	7716.	37376.	3837.	48929.
1956.	4.	5699.	41231.	4277.	51207.
1957.	1.	11254.	19672.	2270.	33196.
1957.	2.	9914.	26823.	2747.	39484.
1957.	3.	6921.	45323.	4141.	56385.
1957.	4.	6536.	58877.	5160.	70573.
1958.	1.	12228.	46317.	4754.	63299.
1958.	2.	12972.	47667.	4593.	65232.
1958.	3.	8950.	62325.	5687.	76962.
1958.	4.	7505.	60265.	5577.	73347.
1959.	1.	13629.	38602.	4569.	56800.
1959.	2.	11646.	43746.	4143.	59535.
1959.	3.	10461.	51592.	8961.	71014.
1959.	4.	8524.	56941.	7575.	73040.
1960.	1.	15320.	34994.	5463.	55777.
1960.	2.	13249.	47097.	4670.	65016.
1960.	3.	10687.	67645.	6484.	84816.
1960.	4.	11282.	67116.	6839.	85237.
1961.	1.	18674.	55831.	6609.	81114.
1961.	2.	19589.	53019.	6115.	78723.
1961.	3.	13440.	65211.	5756.	84407.
1961.	4.	11843.	62605.	6100.	80548.
1962.	1.	18559.	42110.	5316.	65985.
1962.	2.	17326.	49405.	5183.	71914.
1962.	3.	13997.	66250.	6407.	86654.
1962.	4.	13152.	63613.	6429.	83194.
1963.	1.	19390.	46720.	5885.	71995.
1963.	2.	19002.	45033.	4934.	68969.
1963.	3.	14359.	60185.	5105.	79649.
1963.	4.	11175.	61044.	5347.	77566.
1964.	1.	18632.	42729.	4707.	66068.
1964.	2.	17722.	47134.	4012.	68868.
1964.	3.	12910.	59758.	3857.	76525.
1964.	4.	9565.	57184.	3741.	70490.
1965.	1.	17546.	36431.	2454.	56431.
1965.	2.	15392.	38923.	1594.	55909.
1965.	3.	12486.	51641.	2230.	66357.
1965.	4.	12290.	53997.	2494.	68781.
1966.	1.	20847.	34144.	1890.	56881.
1966.	2.	17949.	40278.	1791.	60018.
1966.	3.	13431.	53539.	2482.	69452.
1966.	4.	12673.	54658.	2707.	70038.
1967.	1.	21908.	35138.	2303.	59349.
1967.	2.	18856.	43032.	2181.	64069.
1967.	3.	15162.	56829.	2736.	74727.
1967.	4.	13008.	55121.	2987.	71116.

Table D.1.2 (continued)

Estimated End of Quarter Stocks of Iron Ore in the U.S., by Location, 1955-1978. 1/

Year & Quarter		Mine	Furnace	Dock	All Locations
		(thousands of long tons)			
1968.	1.	22771.	32813.	1703.	57287.
1968.	2.	19574.	37680.	1454.	58708.
1968.	3.	15536.	53153.	2424.	71113.
1968.	4.	15620.	53232.	2797.	71649.
1969.	1.	25153.	33416.	1431.	60000.
1969.	2.	23267.	33410.	925.	57602.
1969.	3.	16245.	47331.	1947.	65523.
1969.	4.	13652.	51003.	2648.	67303.
1970.	1.	22265.	32587.	1804.	56656.
1970.	2.	21297.	37844.	2002.	61143.
1970.	3.	14615.	52604.	3106.	70325.
1970.	4.	14304.	52781.	3403.	70488.
1971.	1.	24372.	33860.	1666.	59898.
1971.	2.	22057.	39463.	1409.	62929.
1971.	3.	17945.	55941.	2376.	76262.
1971.	4.	17552.	57738.	3424.	78714.
1972.	1.	26481.	40412.	1826.	68719.
1972.	2.	25952.	39022.	1324.	66298.
1972.	3.	19731.	47980.	1945.	69656.
1972.	4.	14289.	50061.	2612.	66962.
1973.	1.	24174.	29853.	1240.	55267.
1973.	2.	20642.	33204.	1455.	55301.
1973.	3.	14383.	43641.	2267.	60291.
1973.	4.	10418.	45990.	3039.	59447.
1974.	1.	18525.	27073.	1534.	47132.
1974.	2.	15331.	30349.	1850.	47530.
1974.	3.	12363.	38264.	2940.	53567.
1974.	4.	9143.	45247.	3272.	57662.
1975.	1.	16609.	33480.	2586.	52677.
1975.	2.	14299.	40527.	2768.	57594.
1975.	3.	11549.	50376.	4170.	66095.
1975.	4.	11268.	52231.	4614.	68113.
1976.	1.	21984.	37181.	3911.	63076.
1976.	2.	20793.	39852.	3442.	64087.
1976.	3.	15078.	50864.	3389.	69331.
1976.	4.	14026.	56246.	4763.	75035.
1977.	1.	24978.	41804.	3273.	70055.
1977.	2.	23002.	41991.	3509.	68502.
1977.	3.	15739.	46678.	3506.	65923.
1977.	4.	14140.	42271.	2979.	59390.
1978.	1.	21687.	29195.	2202.	53084.
1978.	2.	20968.	28127.	2792.	51887.
1978.	3.	15165.	36738.	2778.	54681.
1978.	4.	12469.	39301.	3569.	55339.

1/ U.S. Department of Commerce, Survey of Current Business, January editions, 1956-1979, page S-32.

Table D.1.3

Projected Quarterly Consumption and Supply of Iron Ore in the U.S., by Source, 1978-2000: Model I.

Year & Quarter	Consumption	Net Addition to Stocks	Net Imports	Domestic Production		
				Total	Minnesota	Rest of Nation
	(thousands of long tons)					
1978 1	33599.	11050.	6505.	16043.	9605.	6439.
1978 2	35378.	-1745.	12842.	24281.	17705.	6576.
1978 3	31867.	-9109.	14917.	26059.	20153.	5906.
1978 4	30851.	-196.	12785.	18262.	11741.	6521.
1979 1	34306.	11050.	7966.	15290.	8812.	6478.
1979 2	36125.	-1745.	11934.	25936.	19030.	6905.
1979 3	32541.	-9109.	14527.	27124.	20884.	6239.
1979 4	31505.	-196.	12374.	19328.	12480.	6847.
1980 1	35036.	11050.	7738.	16247.	9445.	6802.
1980 2	36894.	-1745.	12095.	26545.	19308.	7237.
1980 3	33236.	-9109.	14177.	28169.	21593.	6575.
1980 4	32180.	-196.	12210.	20166.	12991.	7175.
1981 1	35620.	11050.	7458.	17112.	9984.	7128.
1981 2	37512.	-1745.	11909.	27347.	19794.	7553.
1981 3	33794.	-9109.	13968.	28934.	22039.	6895.
1981 4	32721.	-196.	11931.	20986.	13497.	7489.
1982 1	36220.	11050.	7290.	17880.	10441.	7440.
1982 2	38145.	-1745.	11735.	28155.	20283.	7872.
1982 3	34366.	-9109.	13733.	29742.	22525.	7217.
1982 4	33276.	-196.	11712.	21760.	13956.	7804.
1983 1	36836.	11050.	7124.	18662.	10909.	7753.
1983 2	38795.	-1745.	11587.	28953.	20762.	8191.
1983 3	34953.	-9109.	13503.	30559.	23019.	7540.
1983 4	33846.	-196.	11495.	22547.	14426.	8121.
1984 1	37468.	11050.	6977.	19441.	11373.	8068.
1984 2	39462.	-1745.	11445.	29762.	21249.	8513.
1984 3	35555.	-9109.	13283.	31380.	23515.	7865.
1984 4	34430.	-196.	11285.	23341.	14902.	8439.
1985 1	38116.	11050.	6840.	20226.	11842.	8384.
1985 2	40146.	-1745.	11316.	30575.	21739.	8836.
1985 3	36172.	-9109.	13071.	32210.	24018.	8192.
1985 4	35028.	-196.	11084.	24141.	15382.	8759.
1986 1	38696.	11050.	6628.	21018.	12316.	8702.
1986 2	40758.	-1745.	11144.	31359.	22207.	9152.
1986 3	36725.	-9109.	12821.	33013.	24501.	8511.
1986 4	35565.	-196.	10844.	24917.	15845.	9072.
1987 1	39291.	11050.	6453.	21787.	12773.	9014.
1987 2	41385.	-1745.	10977.	32153.	22684.	9469.
1987 3	37291.	-9109.	12583.	33816.	24984.	8832.
1987 4	36114.	-196.	10614.	25696.	16309.	9386.
1988 1	39898.	11050.	6290.	22558.	13232.	9326.
1988 2	42026.	-1745.	10822.	32950.	23161.	9788.
1988 3	37869.	-9109.	12351.	34628.	25473.	9155.
1988 4	36675.	-196.	10392.	26479.	16776.	9702.

Projected Quarterly Consumption and Supply of Iron Ore in the U.S., by Source, 1978-2000: Model 1.

Year & Quarter	Consumption	Net Addition to Stocks	Net Imports	Domestic Production Total	Minnesota	Rest of Nation
	(thousands of long tons)					
1989 1	40519.	11050.	6135.	23334.	13694.	9640.
1989 2	42681.	-1745.	10675.	33752.	23643.	10108.
1989 3	38461.	-9109.	12125.	35444.	25966.	9479.
1989 4	37249.	-196.	10177.	27268.	17248.	10019.
1990 1	41154.	11050.	5988.	24115.	14160.	9956.
1990 2	43351.	-1745.	10536.	34560.	24129.	10430.
1990 3	39065.	-9109.	11906.	36267.	26464.	9804.
1990 4	37834.	-196.	9968.	28062.	17724.	10338.
1991 1	41707.	11050.	5755.	24902.	14630.	10272.
1991 2	43935.	-1745.	10348.	35332.	24589.	10743.
1991 3	39592.	-9109.	11642.	37059.	26938.	10120.
1991 4	38346.	-196.	9714.	28828.	18179.	10648.
1992 1	42272.	11050.	5561.	25660.	15079.	10581.
1992 2	44530.	-1745.	10162.	36114.	25056.	11058.
1992 3	40129.	-9109.	11390.	37849.	27411.	10438.
1992 4	38867.	-196.	9469.	29594.	18635.	10960.
1993 1	42847.	11050.	5378.	26420.	15529.	10891.
1993 2	45138.	-1745.	9986.	36896.	25523.	11373.
1993 3	40677.	-9109.	11141.	38645.	27889.	10757.
1993 4	39399.	-196.	9230.	30364.	19092.	11272.
1994 1	43434.	11050.	5201.	27183.	15981.	11202.
1994 2	45757.	-1745.	9818.	37684.	25994.	11690.
1994 3	41236.	-9109.	10898.	39447.	28370.	11077.
1994 4	39940.	-196.	8997.	31139.	19553.	11586.
1995 1	44032.	11050.	5032.	27950.	16437.	11514.
1995 2	46387.	-1745.	9656.	38476.	26468.	12008.
1995 3	41805.	-9109.	10661.	40253.	28855.	11398.
1995 4	40492.	-196.	8770.	31919.	20018.	11901.
1996 1	44641.	11050.	4869.	28722.	16896.	11827.
1996 2	47030.	-1745.	9502.	39273.	26946.	12327.
1996 3	42385.	-9109.	10429.	41064.	29344.	11721.
1996 4	41054.	-196.	8548.	32703.	20486.	12217.
1997 1	45262.	11050.	4713.	29499.	17358.	12141.
1997 2	47684.	-1745.	9355.	40075.	27428.	12647.
1997 3	42975.	-9109.	10203.	41881.	29837.	12045.
1997 4	41627.	-196.	8332.	33491.	20957.	12534.
1998 1	45894.	11050.	4564.	30280.	17824.	12456.
1998 2	48351.	-1745.	9214.	40881.	27913.	12968.
1998 3	43576.	-9109.	9982.	42703.	30333.	12370.
1998 4	42210.	-196.	8121.	34285.	21432.	12852.
1999 1	46537.	11050.	4422.	31065.	18293.	12772.
1999 2	49029.	-1745.	9081.	41693.	28402.	13291.
1999 3	44189.	-9109.	9767.	43530.	30834.	12696.
1999 4	42804.	-196.	7917.	35083.	21911.	13171.
2000 1	47192.	11050.	4287.	31855.	18766.	13090.
2000 2	49720.	-1745.	8955.	42510.	28895.	13615.
2000 3	44812.	-9109.	9558.	44363.	31339.	13024.
2000 4	43408.	-196.	7718.	35886.	22394.	13492.

Table D.1.4

Projected Quarterly Consumption and Supply of Iron Ore and Related Employment, U.S. and Minnesota, 1978-2000: Model II. 1/

Yr. & Qtr.	Cons.	Chg. in Stks.	Im-ports	Domestic Production Total	Minn-sota	Rest of Nation	Emp.Forecast Econo-metric	Techno-logical
1978 1	33599.	5840.	11859.	15900.	9293.	6607.	11286.	12903.
1978 2	35378.	-632.	10898.	25112.	17646.	7466.	13255.	13846.
1978 3	31867.	-4010.	9547.	26330.	19486.	6844.	13561.	14054.
1978 4	30851.	-1202.	13325.	18727.	12169.	6559.	12904.	13227.
1979 1	34306.	5838.	10948.	17520.	10372.	7147.	11526.	13015.
1979 2	36125.	-620.	10595.	26149.	18374.	7776.	13370.	13878.
1979 3	32541.	-3989.	9340.	27191.	20010.	7181.	13632.	14054.
1979 4	31505.	-1220.	13057.	19668.	12839.	6829.	13051.	13281.
1980 1	35036.	5814.	10527.	18695.	11268.	7427.	11681.	12933.
1980 2	36894.	-583.	10589.	26888.	18800.	8088.	13418.	13708.
1980 3	33236.	-3970.	9330.	27876.	20357.	7519.	13666.	13868.
1980 4	32180.	-1241.	12902.	20519.	13417.	7102.	13163.	13154.
1981 1	35620.	5783.	10114.	19723.	12014.	7709.	11777.	12759.
1981 2	37512.	-543.	10490.	27565.	19181.	8384.	13455.	13464.
1981 3	33794.	-3945.	9268.	28470.	20628.	7842.	13685.	13606.
1981 4	32721.	-1266.	12684.	21304.	13943.	7360.	13257.	12949.
1982 1	36220.	5747.	9780.	20693.	12717.	7976.	11852.	12562.
1982 2	38145.	-499.	10409.	28235.	19553.	8683.	13491.	13203.
1982 3	34366.	-3915.	9215.	29066.	20900.	8166.	13705.	13329.
1982 4	33276.	-1295.	12487.	22084.	14464.	7620.	13347.	12726.
1983 1	36836.	5704.	9469.	21663.	13419.	8245.	11922.	12357.
1983 2	38795.	-451.	10340.	28906.	19924.	8983.	13527.	12939.
1983 3	34953.	-3879.	9165.	29667.	21175.	8492.	13726.	13051.
1983 4	33846.	-1327.	12302.	22870.	14989.	7881.	13435.	12497.
1984 1	37468.	5656.	9174.	22638.	14123.	8515.	11987.	12147.
1984 2	39462.	-399.	10278.	29583.	20299.	9284.	13564.	12675.
1984 3	35555.	-3838.	9119.	30274.	21454.	8820.	13749.	12774.
1984 4	34430.	-1362.	12130.	23662.	15518.	8144.	13522.	12266.
1985 1	38116.	5601.	8896.	23619.	14831.	8787.	12048.	11918.
1985 2	40146.	-343.	10222.	30266.	20679.	9588.	13602.	12395.
1985 3	36172.	-3792.	9077.	30888.	21738.	9149.	13773.	12481.
1985 4	35028.	-1401.	11969.	24460.	16051.	8409.	13607.	12017.
1986 1	38696.	5541.	8551.	24605.	15544.	9061.	12107.	11677.
1986 2	40758.	-283.	10118.	30923.	21039.	9884.	13636.	12105.
1986 3	36725.	-3741.	8990.	31476.	22005.	9472.	13794.	12180.
1986 4	35565.	-1443.	11773.	25235.	16569.	8666.	13687.	11757.
1987 1	39291.	5475.	8246.	25569.	16241.	9328.	12158.	11432.
1987 2	41385.	-219.	10018.	31587.	21405.	10181.	13671.	11814.
1987 3	37291.	-3685.	8909.	32067.	22272.	9795.	13815.	11879.
1987 4	36114.	-1489.	11589.	26013.	17088.	8925.	13765.	11494.
1988 1	39898.	5404.	7958.	26536.	16940.	9596.	12207.	11185.
1988 2	42026.	-151.	9923.	32254.	21774.	10481.	13707.	11526.
1988 3	37869.	-3624.	8829.	32664.	22544.	10120.	13838.	11581.
1988 4	36675.	-1538.	11417.	26796.	17610.	9186.	13842.	11232.

1/ Consumption and production are measured in thousands of long tons, employment is measured in thousands.

Table D.1.4

Projected Quarterly Consumption and Supply of Iron Ore and Related Employment, U.S. and Minnesota, 1978-2000: Model II.

Yr. & Qtr.	Cons.	Chg. in Stks.	Imports	Domestic Production			Emp. Forecast	
				Total	Minnesota	Rest of Nation	Econometric	Technological
1989 1	40519.	5326.	7685.	27508.	17642.	9866.	12253.	10938.
1989 2	42681.	-80.	9834.	32927.	22146.	10781.	13743.	11242.
1989 3	38461.	-3558.	8751.	33267.	22821.	10447.	13862.	11287.
1989 4	37249.	-1590.	11254.	27584.	18136.	9448.	13918.	10972.
1990 1	41154.	5244.	7426.	28484.	18347.	10136.	12298.	10676.
1990 2	43351.	-4.	9750.	33605.	22522.	11083.	13781.	10944.
1990 3	39065.	-3487.	8676.	33875.	23101.	10775.	13887.	10981.
1990 4	37834.	-1645.	11103.	28376.	18666.	9711.	13993.	10696.
1991 1	41707.	5155.	7087.	29465.	19056.	10409.	12340.	10407.
1991 2	43935.	74.	9610.	34251.	22874.	11376.	13813.	10641.
1991 3	39592.	-3410.	8549.	34453.	23360.	11094.	13908.	10670.
1991 4	38346.	-1704.	10907.	29142.	19176.	9966.	14062.	10415.
1992 1	42272.	5062.	6790.	30420.	19747.	10673.	12377.	10138.
1992 2	44530.	157.	9470.	34904.	23233.	11671.	13847.	10340.
1992 3	40129.	-3330.	8427.	35032.	23618.	11414.	13929.	10363.
1992 4	38867.	-1765.	10724.	29909.	19688.	10221.	14130.	10134.
1993 1	42847.	4963.	6509.	31376.	20438.	10938.	12413.	9871.
1993 2	45138.	243.	9336.	35559.	23592.	11966.	13881.	10045.
1993 3	40677.	-3244.	8305.	35616.	23881.	11735.	13951.	10061.
1993 4	39399.	-1830.	10549.	30680.	20201.	10479.	14197.	9858.
1994 1	43434.	4858.	6240.	32336.	21131.	11204.	12447.	9607.
1994 2	45757.	333.	9206.	36218.	23955.	12263.	13915.	9756.
1994 3	41236.	-3154.	8185.	36204.	24146.	12058.	13974.	9766.
1994 4	39940.	-1898.	10384.	31455.	20718.	10737.	14264.	9585.
1995 1	44032.	4748.	5984.	33300.	21828.	11472.	12480.	9331.
1995 2	46387.	426.	9080.	36881.	24320.	12561.	13950.	9456.
1995 3	41805.	-3059.	8066.	36797.	24416.	12382.	13998.	9460.
1995 4	40492.	-1969.	10227.	32234.	21238.	10996.	14330.	9301.
1996 1	44641.	4633.	5740.	34268.	22527.	11740.	12511.	9059.
1996 2	47030.	523.	8957.	37549.	24689.	12861.	13985.	9162.
1996 3	42385.	-2959.	7949.	37395.	24688.	12707.	14023.	9162.
1996 4	41054.	-2043.	10080.	33017.	21760.	11257.	14395.	9023.
1997 1	45262.	4513.	5509.	35240.	23230.	12010.	12542.	8793.
1997 2	47684.	624.	8838.	38222.	25061.	13161.	14021.	8875.
1997 3	42975.	-2855.	7832.	37997.	24964.	13033.	14048.	8871.
1997 4	41627.	-2120.	9943.	33805.	22286.	11519.	14459.	8750.
1998 1	45894.	4388.	5290.	36216.	23935.	12281.	12573.	8531.
1998 2	48351.	729.	8724.	38898.	25436.	13463.	14057.	8596.
1998 3	43576.	-2746.	7718.	38604.	25243.	13361.	14074.	8588.
1998 4	42210.	-2200.	9814.	34596.	22815.	11781.	14523.	8483.
1999 1	46537.	4257.	5084.	37196.	24643.	12553.	12602.	8275.
1999 2	49029.	837.	8613.	39580.	25814.	13766.	14093.	8323.
1999 3	44189.	-2632.	7605.	39216.	25526.	13690.	14100.	8311.
1999 4	42804.	-2283.	9695.	35392.	23347.	12045.	14587.	8222.
2000 1	47192.	4122.	4890.	38180.	25355.	12826.	12630.	8025.
2000 2	49720.	949.	8506.	40266.	26196.	14070.	14130.	8058.
2000 3	44812.	-2514.	7493.	39833.	25812.	14021.	14127.	8043.
2000 4	43408.	-2369.	9584.	36193.	23882.	12311.	14649.	7968.

Table D.1.5

Projected Quarterly Levels,and Changes in Levels, of Domestic Iron Ore Stocks, 1978-2000.

Yr. & Qtr.	Absolute Stock Levels				Changes in Stock Levels			
	Total	At Mines	At Furnaces	At Docks	Total	At Mines	At Furnaces	At Docks
				(1,000 long tons)				
1978 1	57267.	20837.	33738.	2692.	5840.	-8628.	13321.	1147.
1978 2	57899.	18912.	36131.	2856.	-632.	1925.	-2393.	-163.
1978 3	61909.	14002.	44567.	3340.	-4010.	4910.	-8436.	-484.
1978 4	63111.	12229.	47053.	3829.	-1202.	1773.	-2486.	-489.
1979 1	57273.	20880.	33715.	2678.	5838.	-8650.	13338.	1151.
1979 2	57892.	18948.	36105.	2839.	-620.	1931.	-2390.	-161.
1979 3	61881.	14028.	44535.	3319.	-3989.	4921.	-8430.	-480.
1979 4	63101.	12251.	47033.	3816.	-1220.	1776.	-2499.	-498.
1980 1	57287.	20926.	33698.	2663.	5814.	-8675.	13335.	1153.
1980 2	57870.	18988.	36063.	2819.	-583.	1939.	-2366.	-156.
1980 3	61840.	14055.	44490.	3295.	-3970.	4933.	-8427.	-476.
1980 4	63081.	12275.	47004.	3802.	-1241.	1780.	-2514.	-507.
1981 1	57298.	20977.	33675.	2646.	5783.	-8702.	13329.	1156.
1981 2	57841.	19030.	36014.	2797.	-543.	1947.	-2339.	-151.
1981 3	61786.	14084.	44434.	3268.	-3945.	4946.	-8420.	-471.
1981 4	63052.	12301.	46966.	3786.	-1266.	1783.	-2532.	-518.
1982 1	57306.	21031.	33647.	2627.	5747.	-8731.	13319.	1158.
1982 2	57805.	19076.	35956.	2773.	-499.	1955.	-2309.	-146.
1982 3	61719.	14115.	44366.	3239.	-3915.	4961.	-8410.	-466.
1982 4	63014.	12328.	46918.	3768.	-1295.	1787.	-2553.	-529.
1983 1	57310.	21090.	33614.	2607.	5704.	-8762.	13304.	1161.
1983 2	57761.	19125.	35890.	2747.	-451.	1965.	-2276.	-140.
1983 3	61641.	14148.	44286.	3207.	-3879.	4977.	-8396.	-460.
1983 4	62967.	12357.	46862.	3749.	-1327.	1791.	-2576.	-542.
1984 1	57312.	21152.	33576.	2584.	5656.	-8795.	13286.	1164.
1984 2	57711.	19176.	35815.	2719.	-399.	1975.	-2239.	-135.
1984 3	61549.	14183.	44194.	3172.	-3838.	4993.	-8378.	-453.
1984 4	62911.	12388.	46796.	3728.	-1362.	1796.	-2602.	-555.
1985 1	57310.	21218.	33533.	2560.	5601.	-8830.	13263.	1168.
1985 2	57653.	19231.	35732.	2689.	-343.	1986.	-2200.	-129.
1985 3	61445.	14220.	44090.	3135.	-3792.	5011.	-8357.	-446.
1985 4	62846.	12420.	46721.	3705.	-1401.	1800.	-2631.	-570.
1986 1	57305.	21287.	33484.	2534.	5541.	-8867.	13237.	1171.
1986 2	57588.	19289.	35642.	2657.	-283.	1998.	-2158.	-123.
1986 3	61329.	14259.	43975.	3096.	-3741.	5030.	-8333.	-439.
1986 4	62772.	12454.	46637.	3681.	-1443.	1805.	-2663.	-586.
1987 1	57297.	21360.	33431.	2506.	5475.	-8907.	13207.	1175.
1987 2	57516.	19350.	35543.	2623.	-219.	2011.	-2113.	-117.
1987 3	61201.	14299.	43848.	3054.	-3685.	5050.	-8305.	-430.
1987 4	62690.	12489.	46545.	3656.	-1489.	1810.	-2697.	-602.
1988 1	57286.	21437.	33372.	2477.	5404.	-8948.	13172.	1179.
1988 2	57438.	19413.	35437.	2588.	-151.	2024.	-2064.	-111.
1988 3	61062.	14342.	43710.	3009.	-3624.	5071.	-8274.	-422.
1988 4	62599.	12527.	46444.	3629.	-1538.	1815.	-2733.	-620.

Table D.1.5

Projected Quarterly Levels,and Changes in Levels, of Domestic Iron Ore Stocks, 1978-2000.

Yr. & Qtr.	Absolute Stock Levels Total	At Mines	At Furnaces	At Docks	Changes in Stock Levels Total	At Mines	At Furnaces	At Docks
				(1,000 long tons)				
1989 1	57273.	21518.	33309.	2445.	5326.	-8991.	13134.	1184.
1989 2	57353.	19480.	35322.	2550.	-80.	2038.	-2013.	-105.
1989 3	60910.	14386.	43562.	2963.	-3558.	5094.	-8239.	-412.
1989 4	62500.	12566.	46334.	3601.	-1590.	1821.	-2772.	-638.
1990 1	57256.	21602.	33242.	2413.	5244.	-9037.	13092.	1188.
1990 2	57261.	19549.	35200.	2511.	-4.	2053.	-1959.	-98.
1990 3	60747.	14432.	43402.	2913.	-3487.	5117.	-8201.	-402.
1990 4	62392.	12606.	46215.	3571.	-1645.	1826.	-2814.	-657.
1991 1	57237.	21690.	33169.	2378.	5155.	-9084.	13047.	1193.
1991 2	57162.	19622.	35071.	2470.	74.	2068.	-1902.	-92.
1991 3	60573.	14480.	43231.	2862.	-3410.	5141.	-8160.	-392.
1991 4	62276.	12648.	46089.	3540.	-1704.	1832.	-2858.	-678.
1992 1	57215.	21781.	33092.	2342.	5062.	-9133.	12997.	1198.
1992 2	57058.	19697.	34934.	2427.	157.	2084.	-1842.	-85.
1992 3	60388.	14530.	43050.	2808.	-3330.	5167.	-8116.	-381.
1992 4	62153.	12692.	45954.	3507.	-1765.	1838.	-2904.	-699.
1993 1	57190.	21876.	33010.	2304.	4963.	-9184.	12944.	1203.
1993 2	56947.	19775.	34790.	2383.	243.	2101.	-1780.	-79.
1993 3	60191.	14581.	42858.	2752.	-3244.	5193.	-8068.	-369.
1993 4	62021.	12737.	45812.	3473.	-1830.	1844.	-2953.	-721.
1994 1	57163.	21974.	32924.	2265.	4858.	-9237.	12887.	1208.
1994 2	56831.	19855.	34639.	2337.	333.	2119.	-1715.	-72.
1994 3	59984.	14635.	42656.	2693.	-3154.	5221.	-8017.	-357.
1994 4	61882.	12784.	45661.	3438.	-1898.	1851.	-3005.	-744.
1995 1	57134.	22076.	32834.	2224.	4748.	-9292.	12827.	1213.
1995 2	56708.	19939.	34480.	2289.	426.	2137.	-1646.	-64.
1995 3	59766.	14690.	42444.	2633.	-3059.	5249.	-7964.	-344.
1995 4	61735.	12832.	45502.	3401.	-1969.	1857.	-3058.	-768.
1996 1	57102.	22181.	32739.	2182.	4633.	-9349.	12763.	1219.
1996 2	56579.	20025.	34315.	2239.	523.	2156.	-1575.	-57.
1996 3	59537.	14746.	42221.	2570.	-2959.	5279.	-7907.	-331.
1996 4	61580.	12882.	45336.	3363.	-2043.	1864.	-3114.	-793.
1997 1	57067.	22289.	32640.	2138.	4513.	-9407.	12695.	1225.
1997 2	56443.	20114.	34142.	2188.	624.	2176.	-1502.	-50.
1997 3	59298.	14805.	41988.	2505.	-2855.	5309.	-7847.	-317.
1997 4	61418.	12933.	45161.	3323.	-2120.	1871.	-3173.	-819.
1998 1	57030.	22401.	32536.	2092.	4388.	-9468.	12624.	1231.
1998 2	56301.	20205.	33961.	2135.	729.	2196.	-1425.	-42.
1998 3	59047.	14865.	41745.	2437.	-2746.	5341.	-7783.	-303.
1998 4	61247.	12986.	44978.	3283.	-2200.	1878.	-3233.	-845.
1999 1	56990.	22516.	32428.	2045.	4257.	-9530.	12550.	1237.
1999 2	56153.	20299.	33774.	2080.	837.	2217.	-1346.	-34.
1999 3	58785.	14926.	41491.	2368.	-2632.	5373.	-7717.	-288.
1999 4	61068.	13040.	44788.	3240.	-2283.	1886.	-3297.	-873.
2000 1	56947.	22634.	32316.	1997.	4122.	-9594.	12472.	1244.
2000 2	55998.	20396.	33579.	2023.	949.	2238.	-1264.	-26.
2000 3	58512.	14990.	41227.	2296.	-2514.	5406.	-7648.	-273.
2000 4	60882.	13096.	44589.	3197.	-2369.	1893.	-3362.	-901.

Appendix D.2: Gross National Product Forecasts

Historical GNP data from the 1955 to 1978 period are listed in Table D.2.1. These values were regressed against constant dummy variables to find the average influence of seasonality. The following coefficients, when applied to the annual GNP figures, yield predictions of quarterly values at seasonally adjusted annual rates.

Table D.2.2

Seasonality Index for Gross National Product in the U.S., 1955-1978.

Quarter	Seasonality Index
I	0.98598
II	0.99565
III	1.00541
IV	1.01296

In order to predict future levels of GNP the annual rates of increase listed in Table D.2.3 were applied, beginning with the estimated annual GNP during 1978 (1,147 billion 1967 dollars). Once the seasonal index indicated in Table B.2 had been applied, the GNP projections listed in Table D.2.4 were obtained.

Table D.2.3

Projected Annual Rate of Change in Gross National Product in the U.S., 1978-2000. 1/

Period	Annual Rate of Change
	(percent)
1978-1980	4.43
1980-1985	3 60
1985-1990	3.22
1990-2000	2.82

1/ Based on data from: Normal C. Saunders, The U.S. Economy to 1990: Two Projections for Growth, Monthly Labor Review, December 1978, p. 40.

Table D.2.1

Estimated Gross National Product (in 1967 Dollars), by Quarter, 1955-1978.[1/][2/]

Year	Annual Average	Quarter I	II	III	IV
		(billion dollars)			
1955	542	531	539	547	552
1956	554	550	553	553	559
1957	564	563	564	568	560
1958	562	549	553	567	581
1959	594	588	601	595	601
1960	610	613	612	609	606
1961	625	610	620	628	643
1962	661	652	661	666	667
1963	688	673	682	694	701
1964	724	713	722	729	732
1965	766	747	759	772	788
1966	812	803	808	816	822
1967	834	823	829	839	846
1968	871	854	869	879	881
1969	893	890	894	897	892
1970	890	889	889	896	887
1971	917	907	913	920	928
1972	969	945	963	975	995
1973	1,021	1,016	1,017	1,024	1,029
1974	1,002	1,018	1,014	1,007	993
1975	995	970	985	1,010	1,016
1976	1,052	1,039	1,050	1,057	1,063
1977	1,103	1,082	1,097	1,112	1,121
1978	1,147	1,121	1,144	1,152	1,171

1/ U.S. Department of Commerce, Survey of Current Business, January 1955-July 1978, and April 1979.

2/ The data source lists the GNP in $1972. The values have been changed to $1967 by using the conversion factors listed in the U.S. Survey of Current Business, July 1974.

Table D.2.4

Projected Gross National Product (in 1967 dollars), in the U.S., by Quarter, 1978-2000.

Year	Total	Quarter Total			
		I	II	III	IV
		(billion dollars)			
1978	1147.09	1131.01	1142.10	1153.29	1161.95
1979	1197.90	1181.10	1192.69	1204.38	1213.42
1980	1250.95	1233.41	1245.51	1257.72	1267.16
1981	1295.96	1277.79	1290.32	1302.97	1312.75
1982	1342.58	1323.75	1336.74	1349.84	1359.98
1983	1390.87	1371.37	1384.82	1398.40	1408.90
1984	1440.91	1420.71	1434.64	1448.71	1459.58
1985	1492.75	1471.82	1486.25	1500.82	1512.09
1986	1540.79	1519.19	1534.09	1549.13	1560.76
1987	1590.38	1568.09	1583.47	1598.99	1610.99
1988	1641.57	1618.56	1634.43	1650.45	1662.85
1989	1694.41	1670.66	1687.04	1703.58	1716.37
1990	1748.95	1724.43	1741.34	1758.41	1771.61
1991	1798.27	1773.05	1790.44	1807.99	1821.57
1992	1848.98	1823.05	1840.93	1858.98	1872.94
1993	1901.12	1874.46	1892.85	1911.40	1925.76
1994	1954.73	1927.33	1946.23	1965.31	1980.07
1995	2009.86	1981.68	2001.11	2020.73	2035.90
1996	2066.53	2037.56	2057.54	2077.71	2093.32
1997	2124.81	2095.02	2115.57	2136.31	2152.35
1998	2184.73	2154.10	2175.22	2196.54	2213.04
1999	2246.34	2214.84	2236.57	2258.49	2275.45
2000	2309.68	2277.30	2299.63	2322.18	2339.61