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An econometric model of the world nickel industry

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An Econometric Model of
the World Nickel Industry

by

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ABSTRACT

The Third United Nations Conference on the Law of the Sea has been concluded in the spring of 1982 with the adoption of a convention text. The acceptance of this text (signature and ratification) by the necessary number of states is still highly uncertain. The major disagreements relate to the convention's seabed mining regime, in particular the provisions for production controls and technology transfer.

Among the four metals which can be recovered from the seabed - manganese nodules containing manganese, cobalt, copper and nickel - over half of the potential revenues would come from nickel. Conditions in the nickel market will have an impact on investment decisions in seabed mining and the nickel market itself may be significantly affected by nickel output from manganese nodules. The purpose of this paper is to present and estimate an econometric model for the world nickel industry. Furthermore, in order to quantify the impact of alternative seabed mining regimes on the future price of nickel as well as on the output of nickel from current land-based sources, a simulation analysis is provided. Such a simulation model is also helpful in estimating the revenue losses that land-based producers might incur as a result of seabed mining.

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I. Introduction

Nickel (NI), belonging to the iron-cobalt family, is the second most important alloying metal in specialty steels, next to chromium. The light gray metal which is tough, ductile and partially magnetic has an atomic number of 28, an atomic weight of 58.70, and a melting point of 1452 degrees celsius¹. Nickel was first discovered in 1751; the first nickel steel was not produced until 1920 when Michael Faraday added nickel to horseshoe iron. He subsequently formulated the laws of electrolysis which contributed to the development of nickel plating².

Nickel is highly resistant to corrosion from many media. It is mainly used as an alloying element because it adds corrosion resistance, strength and toughness at high temperatures. About 85 % of total nickel consumption is in the form of alloys. Unalloyed uses of nickel are primarily for electroplating and coinage.

II. A Descriptive Analysis of the Supply and Demand of Nickel

The nickel market has not been typified as one with supply-demand equilibrium. The periods from 1950 to 1955 and from 1966 to 1969 were ones of severe shortages, mostly caused by unanticipated increases in demand and/or nickel strikes at major producing firms such as INCO³ and Falconbridge. The periods of excess supply have been even more frequent. The market for nickel was generally weak in the periods 1962 - 1963, 1971 - 1972 and 1978.

¹ American Metal Market (1980) p. 143.

² Hilmy (1979) p. 1.

³ International Nickel Company (Canada).

Recessions in 1958, 1971, 1974 - 1975 and 1980 have also created excess supply situations. In periods of shortages the leading producers formerly preferred to ration supplies, maintaining a stable price rather than to let prices respond to the market situation. However, price increases in the late 1960's and in 1979 suggest that this no longer seems to be the case¹. Similarly, major producers usually respond to the excess supply situation by cutting back output. Production was reduced in 1958, 1962, 1972 - 1973, and in 1978 principally in those countries where INCO, Falconbridge and Société Le Nickel (SLN) hold mining interests. In recent years, prices are also being adjusted in response to excess supply. The most striking example of such a reduction in the price of nickel occurred in 1978 when the price of nickel fell from 241 cents per pound in 1977 to 193 cents per pound in 1978.

1. Past and Future Pattern of Consumption

Nickel consumption shows a marked cyclical tendency. Consumption of nickel almost doubled from 1948 to 1959. This apparent rate of growth of approximately 9 percent per annum was also maintained from 1959 to 1969 when nickel consumption again doubled from 249.2 thousand metric tons in 1959 to 502.8 thousand tons in 1969. However, these were the periods of exceptionally rapid economic growth when the industrialized nations were catching up from the World War II levels to the US level of per capita metals consumption. Furthermore, growth in the US and other nations' defense spending due to the Korean War, the "Cold War", and the Vietnam War have, in addition to the expansion of capital goods industries, all contributed to the high rate of growth in nickel consumption.

¹ Our empirical results support this view. For more detail see the price setting equation (A1).

This high rate of growth in nickel consumption over a fairly long period of time led the producers into extrapolating this trend into the future. Plans for expanding capacities were made accordingly. Heavy investments were made in new nickel mining projects in Australia, the Dominican Republic, the Philippines, Botswana, Indonesia, Guatemala and other countries in the late 1960's and in the early 1970's. Also the optimistic rates of growth for nickel consumption materialized in the first half of the 1970's. However, world consumption of nickel in 1975, 1976, 1977 and 1978 fell below its 1974 level. From 1974 to 1980 the cumulative nickel consumption grew only by 10 percent.

The reduction in nickel consumption in recent years is to be attributed to the slowdown in economic activity in industrialized countries, the end of the Vietnam War, and the reduction in nickel consumption per unit of GNP in the major nickel consuming nations which are entering the advanced stages of economic development where the metal consumption falls as a result of the shift in demand towards services and other goods which are not metal intensive.

a) Major Consuming Countries

The United States have always been the biggest consumer of nickel. However, the share of US consumption of nickel has steadily declined from more than 60 per cent of the world's consumption in 1948 to about 22 per cent in 1979. On the other hand, Japan's share increased from less than .4 per cent in 1948 to about 18 per cent in 1979. The share of East-block nations has also increased from 13 per cent in 1948 to about 24 per cent in 1979. The shares of Germany, France, Sweden and Italy have also increased, while the United Kingdom's share has declined from 12 per cent in 1948 to about 5 per cent in 1979.

The developing countries consumed very little nickel in the early 1950's. Since the beginning of the 1970's their combined share has grown rapidly, but it still accounts for only 2 per cent of the world's total consumption. Mexico, Brazil and India, which have been experiencing rapid industrialization, account for practically all the increment in the developing countries' nickel consumption. From the mid-1960's to 1976, the use of nickel in these three countries increased by 45 per cent, 16 per cent and 13 percent per annum, respectively¹.

The over-all growth in the demand for nickel is strongly correlated with the rate of growth in the industrialized countries' GNP and its components, mainly gross fixed investment and durable consumer goods, reflecting the level of a country's technology or the complexity of its industry². Iron and steel production, which account for two-thirds of total nickel consumption in intermediate uses, are also highly correlated with nickel consumption. Trend growth rates for these variables are compared in table (1).

The exceptionally high rates of growth of nickel consumption for some of the developing countries can be explained by the so-called "nickel-intensity" argument. The nickel-intensity, defined as the volume of nickel used by producers of semi-fabricated products per unit of GNP, tends to change in the process of economic development. Nickel-intensity is low in predominantly agricultural countries. In the early stages of industrialization a sharp increase in nickel consumption usually accompanies increases in GNP. This reflects the sharp increase in demand for metal intensive investment and consumer goods - all being heavy users of nickel. Brazil and Mexico have fallen in this category.

¹ Hilmy (1979) p. 4.

² This section relies heavily on Hilmy (1979).

Table (1) - Comparative Trend Growth of Nickel Demand in World Market Economies, GNP, Investment, and Crude Steel Production, 1955 - 1974

	% of Total Market Economies	Average Annual Percentage Growth Rates			
		Nickel Demand	GNP	Crude Steel Production	NRFI ^b
Developed Countries					
USA	36	2.6	3.7	1.6	3.7
Western Europe	38	7.3	4.7	4.6	4.7
Japan ^b	21	15.4	10.5	13.8	10.5
Others	3				
Total	98	6.6	4.6	4.9	4.6
Developing ^a Countries	2	16.3	5.9	9.2	N A

^a 1960 - 1973

^b NRFI = non-residential fixed investment at constant prices.

Source: Joseph Hilmy, "Old Nick", An Anatomy of the Nickel Industry and its Future, Commodity Note No. 13, World Bank, September 1979

In the more advanced economies, nickel consumption growth tends to match that of GNP; the reason being that the pattern of demand changes in favor of services, using less metals, and in favor of goods with high value added but relatively low metal content, e. g., computers and electronics. Therefore, nickel-intensity levels off at that stage and then starts to decline. Diagram (1) and Table (2) illustrate these points.

b) Nickel Consumption by Class-Type and End-Uses

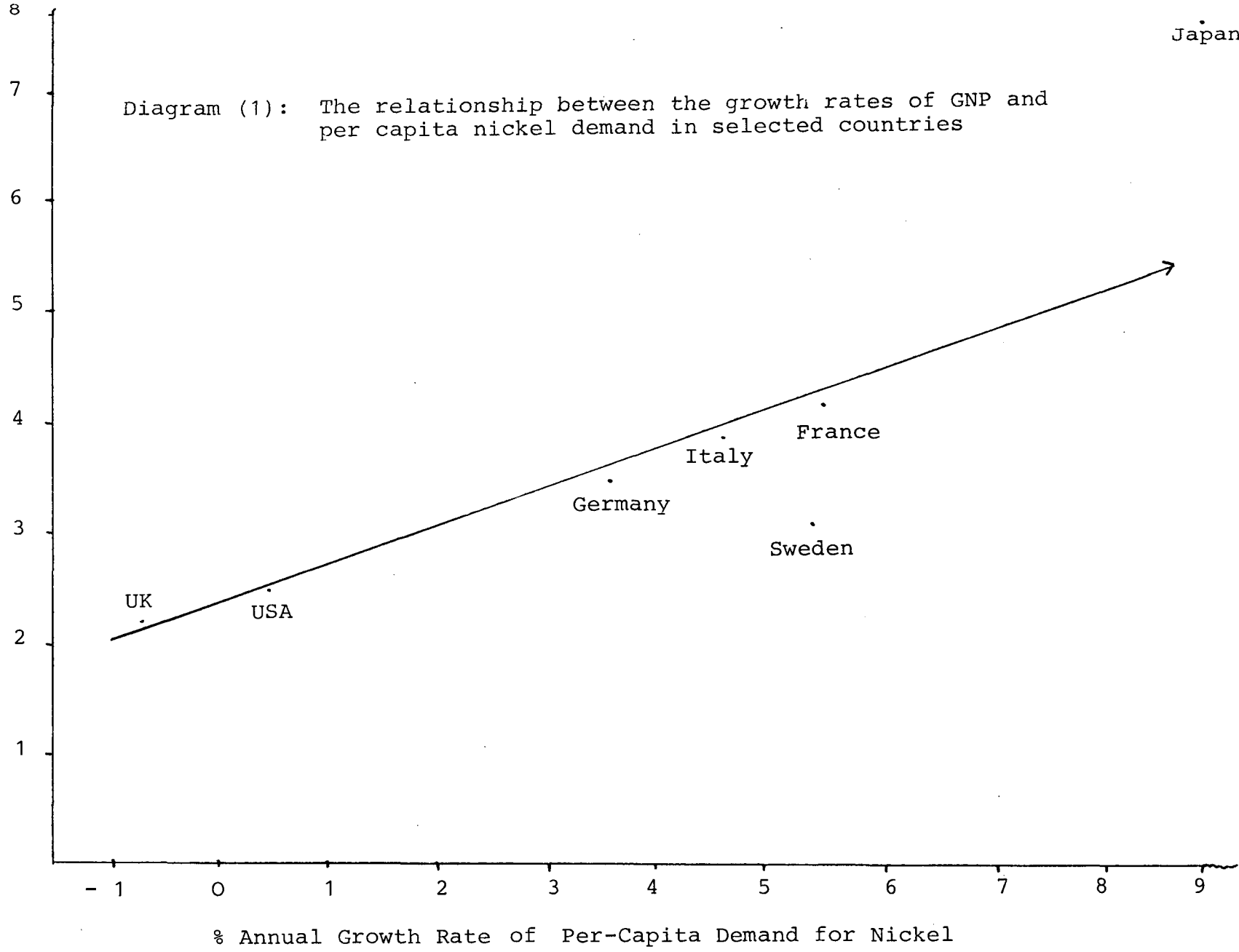
Nickel consumption is typically identified by three general product classes. These are class I, II and III nickel products. Class I products are nearly pure and sometimes referred to as metal nickel with a nickel content greater than 99.25 percent. Class I products include electrolytic cathodes, carbonyl nickel pellets, nickel 98 granules, briquettes, rondelles and ponder¹. Of the class I products, the electrolytic cathodes and carbonyl pellets have nearly universal application. The other products are more restricted in use.

The nickel content of class II products varies in the range of about 20 to 95 percent. Class II products include various grades of ferronickel and nickel oxides. These products have more limited application than the class I products. Nickel salts and other specialized products with even more limited applications are sometimes classified as class II or class III products. Since they constitute such a small share of nickel products, they are generally referred to as class II products.

¹ Mohide et al. (1977), pp. 142 - 144.

Diagram (1): The relationship between the growth rates of GNP and per capita nickel demand in selected countries

Annual GNP Growth Rate



Source: Hilmy (1979), p. 9.

Table (2) - Nickel Consumption - Industrial Production Ratios of Japan, Germany, France and the United Kingdom⁺

	Japan	Germany	France	U. K.
1950 - 1951	.122	.225	.193	.31
1954 - 1955	.255	.278	.265	.317
1960 - 1961	.68	.396	.35	.361
1965 - 1966	.67	.427	.335	.40
1970 - 1971	.98	.385	.39	.349
1974 - 1975	.915	.5	.348	.29
1977 - 1978	.822	.54	.32	.289

⁺ These ratios were calculated by dividing nickel consumption (in 1000 of metric tons) by the index of industrial production (1975 = 100) of the respective nation.

Class I products are usually obtained from the sulfide ores rather than from lateritic ores because it is less costly to concentrate sulfide ores to such a pure state¹. However, recent technological advances by INCO and Sherrit Gordon have enabled the production of class I products from lateritic ores on a more competitive basis.

Among the nickel classes, the share of class II products has increased. In the US, the shares of class I, II and III nickel consumption were about 72 percent, 25 percent and 3 percent, respectively, in the 1950's; through the 1960's and early 1970's the shares had changed to about 60 percent, 38 percent and 2 percent for the three respective product classes. The main reason for the increased use of class II products in the US has been technological advance which permitted class I products to be substituted for class II products. This has occurred to a great extent in the manufacture of stainless steel where ferronickel has been displacing other, purer forms of nickel. An estimate of world consumption of nickel by class type in 1976 is as follows²

Class I	55 %
Class II	
Ferronickel	35 %
Nickeloxide	10 %
Class III	1 %.

The share of consumption of class II products can be expected to increase as substitution possibilities are more widely exploited.

¹ For an explanation of sulfide and laterite ores see section 2 below.

² Mohide et. al.(1977), p. 142.

The consumption of nickel by major end use category for the noncommunist world is summarized in Table (3) for the period 1960 to 1976. This table shows that the steel industry, which includes the stainless steel, other alloys and iron and steel casting categories, accounts for more than 60 percent of total nickel consumption. The only category which has increased its share of consumption over the period has been the stainless and heat resistant steels. All of the other categories have grown at a lower rate so that, even though consumption by these other categories has increased in absolute terms, their respective shares of total consumption have declined or remained constant.

The rapid growth in the use of nickel for making stainless steel is due to three main factors. First, technological advances have permitted the use of low quality scrap and low nickel content products, e. g., ferronickel, in the making of stainless steel. Second, ferronickel has a cost advantage over other possible nickel products that could be used and there are abundant supplies of ferronickel on the market. Third, nickel-bearing stainless steel has more favorable welding and anti-corrosive properties than the chromium-bearing stainless steels. There are three general types of stainless steels: austenitic, ferritic, and martensitic. The austenitic stainless steels account for the majority of stainless steel production; Although their share of worldwide stainless steel production is unknown, they account for about 70 to 75 percent of the US stainless steel output. A basic austenitic stainless steel is AISI No. 304, commonly referred to as 18-8 stainless steel. The chemical composition limits for this particular stainless steel are 18 to 20 percent chromium, 8 to 10.5 percent nickel, 0.08 percent (maximum) carbon, 2 percent (maximum) manganese, 0.045 percent (maximum) phosphorus, .03 percent (maximum) sulfur, 1 percent (maximum) silicon, and the balance iron¹.

¹ Mineral Commodity Profile, (1979) p. 4.

Table (3) - Consumption of Nickel by Major End-Use Category
in the Noncommunist World, 1960, 1970, 1974, 1976

	Percent of Total Consumption			
	1966	1970	1974	1976
Stainless and Heat Resistant Steels	33	41	44	44
Electroplating	15	13	14	14
Superalloys	15	14	13	13
Other Alloyed Steels	13	11	11	11
Iron and Steel Castings	12	9	7	7
Copper-Nickel Alloy	4	3	3	3
Other	8	9	8	8

Source: Hilmy (1979) p. 12.

Other kinds of stainless steels are martensitic stainless steels and ferritic stainless steels. Hilmy reports the following categories for the total nickel use stainless steels¹:

Series	Carbon <u>Content (%)</u>	Nickel <u>Content (%)</u>	Chromium <u>Content (%)</u>	Other Usually Small Amounts of:
200	.15	3 - 6	16 - 19	<u>manganese</u>
300	under .15	6 - 22	16 - 26	molybdenum-titanium
400	.12 - 1.2	.6 - 2.5	11 - 18	molybdenum
600	.06 - .07	3 - 8.5	15.5 - 18	copper-aluminium

Austenitic stainless steels fall within the 200- and 300-series. Ferritic steels belong to the 400-series and martensitic steels are also included in special varieties of stainless steels under series 400. The 300-series accounts for about three-quarters of the steel output in the US, its share in total stainless steel is rising.

Nickel use for the production of alloyed steels accounts for about 11 % of total nickel consumption; nickel is the favored alloying element in the structural steel industry, where nickel is used to increase hardness. However, since the 1960's, the use of nickel in alloyed steel has expanded at a lower pace than the overall nickel consumption. There are three major groups of alloy steels in which nickel is used: (1) the AISI alloy steels, (2) the high-strength low-alloy (HSLA) steels, and (3) special alloy tool steels². Nickel may be added to strengthen ferrite and therefore increase the strength of steels that receive no heat treatment. On the other hand, nickel improves the hardenability of steels that are to be heat treated. In case-hardening steels, nickel strengthens both the case and the core, thereby improving wear-resistance and minimizing cracking and spilling. A typical nickel bearing alloy steel, AISI No. 4340, has the following chemical

¹ Hilmy (1979) p. 13; these data are based on industry interviews.

² Mineral Commodity Profile (1979), p. 4

composition: 0.70 to 0.90 percent chromium, 1.65 to 2 percent nickel, 0.38 to 0.43 percent carbon, 0.60 to 0.80 percent manganese, 0.035 percent (maximum) phosphorus, 0.04 percent (maximum) sulfur, 0.2 to 0.35 percent silicon, 0.2 to 0.3 percent molybdenum, with the balance going to iron. Typical uses of alloy steels include crankshafts, axels, gears, shafts, frames, and other parts of cars, trucks, cranes, and earth-moving equipment, machine tool parts and frames, aircraft landing gear components, missile parts, and rock drill parts.

Electroplating is the second largest end-use for nickel, accounting for about 14 percent of total nickel consumption. Nickel is used in electroplating for decorative purposes and as a protection of the base metal against atmospheric corrosion. A major use of electroplating is in the automobile industry where nickel is applied to bumpers. Nickel consumption in this intermediate use grew annually at 5.7 % from 1960 to 1974. For electroplating purposes, cobalt can serve as a substitute for up to 50 percent of the nickel content. At present, however, the price of cobalt does not allow any widespread substitution of cobalt for nickel. The use of plating in a number of applications in most durable and cheaper stainless categories is expected to decrease, while the use of aluminium and plastics is likely to increase. Nickel consumption in this area is expected to increase at a very moderate rate of 1 percent.

The share of the iron and steel castings category in total nickel consumption has shown the largest decrease. Nickel is added up to 5 percent of total content to impart toughness, machineability, and corrosion and wear resistance. The major uses of these products include engine blocks and parts for the automotive and heavy equipment industries and steel mill rollers. Part of the decline in the growth of this use area is due to the fact that automobile engines are decreasing in size, mainly in response to the energy crisis, and that aluminium alloys are being used for more engine applications. A decline in absolute volume was experienced in the 1970's.

Nickel is also used in a number of superalloys, nickel copper alloys, copper-nickel alloys and other nickel alloys. The term "superalloy" was coined after World War II to describe a group of alloys developed for use in high-temperature application in turbo superchargers and gas turbine engines. These alloys possess relatively high tensile and creep strength at temperatures normally prevailing in jet engines (1800° F or higher).

A typical superalloy has the following chemical composition: 19.5 percent chromium, 13.5 percent cobalt, 4.3 percent molybdenum, 1.3 percent aluminium, .10 percent carbon, 3 percent titanium, 2 percent iron, .001 to .10 percent boron, and the balance nickel¹. Nickel-copper alloys comprise alloys of nickel and copper containing more than 50 percent nickel. One of the best known is Monel 400 containing 66 percent nickel plus cobalt and 31.5 percent copper. The Monel alloys have wide applications in food preparation and handling equipment, and for interior trim.

Copper-nickel alloys include a number of cupro-nickel, nickel-silver, and nickel-bearing brasses and bronzes, in which copper is the major constituent. A typical copper-nickel alloy contains 10 percent nickel, .10 percent carbon, 1 percent iron, 1.2 percent manganese, .10 percent silicon, and a copper balance. The cupron-nickels are used mainly in piping, tubing, pumps, and valves for marine service because of their excellent resistance to corrosion and erosion under stress of sea weather. Nickel-molybdenum and other nickel alloys are mainly used in pumps, valves, pipe fittings, shafts and other process equipment for handling acid, alkaline, and bleach solutions².

Other uses of nickel are in alnico (aluminum-nickel-cobalt) alloys, magnets for loudspeakers, magnetos and small generators. Nickel-cadmium batteries are used in applications where the ability to recharge is important such as aerospace uses, portable

¹ Mineral Commodity Profile, (1977), p. 4.

² Ibid, p. 5.

electric appliances, calculators and photographic equipment. Nickel metal and salts are used as catalysts for synthesizing gas, fuel oil and other chemicals. Nickel oxides are used as an undercoating to promote the adherence of porcelain finishes to steel and cast iron products such as household appliances. They are also widely used in coinage.

c) Complements and Substitutes

Other materials can be used as a substitute for nickel in almost all of its applications. However, such a replacement would require increased costs or some sacrifice in the physical or the chemical characteristics and hence affect the price or quality of the product.

Chromium is the principal element in stainless steel and is almost always present in an amount in excess of nickel. In the presence of chromium, nickel has a significant effect on corrosion resistance. Therefore, chromium is a vital complement to nickel in stainless steel production. On the other hand, manganese and nitrogen are used to replace about 1/2 the nickel production of the 200-series stainless steels¹.

Aluminum, molybdenum, cobalt, silicon, titanium, vanadium have all found uses either to enhance resistance to oxidation at high temperatures, add high temperature strength, improve creep resistance, or as a stabilizer in stainless and ferrous super alloys. In most of the stainless steels and ferrous super alloys other alloy additions enhance these properties and do not result in lower nickel additions. The chromium-nickel-cobalt-iron alloys containing 12 % to 30 % cobalt compete with some high nickel alloys and have the effect of lowering nickel consumption².

¹ Mohide et al. (1977) p. 195.

² Ibid, p. 195.

Columbium, molybdenum, chromium, and vanadium can replace nickel in some alloy steels, and cobalt, chromium and columbium-based alloys can be used in place of some nickel-based superalloys. In production of steel alloys and superalloys, manganese, molybdenum, cobalt and titanium could be used as alternative alloying elements in various combinations. However, nickel is often used to make these alternative alloys, although in smaller proportions per unit produced. During nickel shortages, other materials such as copper, chromium, brass, lead, and tin were used in combination to replace nickel in plating in spite of their poorer performance¹. Nevertheless, further research is being done, especially in the direct application of chromium on aluminum and steels. However, new uses of nickel plating such as the black deposits of nickel upon other metals hold considerable promise for use in solar energy applications, because of its high thermal emissivity properties².

The biggest field for substituting nickel is where nickel-bearing material is used for its corrosion resistance, high strength, or special magnetic and electronic properties. Carbon steel clad with titanium could perform satisfactorily in many applications now filled by stainless steels and high nickel alloys. Many plastics have equal or superior corrosion resistance compared with the nickel-bearing materials. Plastic coating on high-strength steels or other material are comparatively inexpensive³.

Other areas where substitution is possible, often at the expense of performance, is in nickel-based iron casting where manganese and molybdenum give the most competition. Several combinations of metals and nonmetals are acceptable for use in storage batteries, which can take the place of the nickel-iron and nickel-cadmium combinations⁴.

¹ Mineral Commodity Profile (1977), p. 12.

² Mohide et al. (1977), p. 196.

³ Hilmy (1979), p. 18.

⁴ Ibid, p. 18.

d) Consumption Prospects

To get a rough picture of the future nickel consumption one has to look at the prospects of the nickel using industries. As mentioned earlier, the production of steel and capital equipments account for most of nickel consumption. Defence spending and the production of arms are among other major sources of demand for nickel. If one is to rely on the future of these industries to forecast future demand for nickel a sharp increase in demand for nickel is very unlikely. Given the present state of the steel industry in most of the industrialized nations, one can not expect a big increase in demand for nickel to originate in this industry. The production of capital equipment is also expected to stagnate at least in the near future. This is mainly due to the current recession in the leading industrialized countries, which are major consumers of nickel. Even if these countries recover from the current recession soon, it is unlikely that the historical rate of growth in nickel consumption will be attained. This, as it was argued before, is due to the "nickel-intensity" argument. Most of the industrialized nations have already reached a stage of economic development where metal requirements per unit of GNP either have already fallen or are starting to fall. However, there are a few economies, such as Brazil and India which are entering the early phases of economic development during which metal requirements per unit of GNP rise quickly.

Other developments which can, at the present time, be of some help to the nickel industry are the present increase in arms production in East-block nations and Western countries and the planned stockpile of nickel by the US government, which amounts to 185.000 metric tons of nickel. Of course, should the seabed output of nickel come on the stream towards the end of the 1980's, it may reduce the price of nickel and hence increase demand.

Given that the overall demand for nickel is price inelastic it is not likely that a sharp increase in the consumption of nickel will result. On the contrary, the output of seabed projects is more likely to challenge the operation of marginal mines. Estimates of the impact of seabed mining on land-based nickel production will be given in chapter IV.

2. Past and Future Patterns of Production

Nickel is produced from two basic ore types, sulfides and oxides. The latter, more commonly termed laterites in the literature, are generally found in land rock deposits and mined by open pit or shaft methods. Laterite ores are located in tropical climates and formed by weatherization of nickel bearing soils that produce deposits with higher concentration of nickel¹. Producer countries of nickel from sulfide deposits include Canada, Australia, South Africa, Zimbabwe, Botswana, Finland, Morocco, Norway and Soviet Union. On the other hand, New Caledonia, Cuba, Dominican Republic, Australia, Greece, United States, Indonesia, Philippines, Brazil, Burma, Albania, Soviet Union, East Germany, Poland and several other centrally planned economies produce nickel from laterite ores.

Between 1950/51 and the late 1970's the worldwide nickel mine production increased at 5.4 % per year, reaching 790 000 tons in 1979. During that period the output of nickel in industrialized countries expanded at a slower rate than in the rest of the world, at 3.9 % annually. Thus their share of world output declined from 76 % in the early 1950's to 50 % in 1975 - 1977.

¹ Hilmy, (1979), p. 20.

The shift in the geographical structure of nickel mining reflects economic as well as technological considerations. Three major factors, all of which occurred in the 1960's, were responsible for this change. Above all, the rise in the price of nickel in the second half of the 1960's made the exploitation of the higher cost laterite ores viable. Further, a first technological breakthrough permitted the processing of laterite ores which exist in developing countries; a second one allowed the use of ferronickel, which is mainly produced from laterites, in the stainless steel industry.

Even though the mining of laterite ores is not so costly, their further treatment is more expensive compared with sulfide ores. They are usually of low grades and the cost of mining and processing them is roughly about 170 % - 180 % of producing nickel from sulfide sources. This is due to the fact that, since obtaining nickel from laterite ores is relatively more energy intensive, the increases in energy costs in 1974 and in 1979/80 have made the production of nickel from laterite ores more costly¹.

The costs of production from sulfide mines have also increased. Some of the world's sulfide nickel deposits, notably in Canada, have been in operation for a long time, and now require deeper digging at generally lower ore grades.

Table (4) shows the production shares of nickel by ore type and major producing country.

¹ For example energy costs per pound of nickel in 1974 were estimated to be US \$ 10 for Canadian sulfide ores, while the corresponding figures for laterite ores were between 41 to 56 cents per pound. For more detail see Hilmy, (1979), p. 53.

Table (4) - Production shares of Nickel by Ore Type and Major Producing Country, Excluding Centrally Planned Economies (%)

Ore Type	1950	1960	1970	1975
Sulfide	45.7	74.8	65.3	60.1
of which Canada	98.9	97.3	84.2	67.5
Laterite	4.3	25.2	34.7	39.9
of which New Caledonia	89.3	80.5	79.1	57.5
Total Ore Production (x 10 ³ metric tons of contained nickel)	118.5	267.1	504.2	595.8

Source: Mohide et al. (1977), pp. 221 - 227.

a) Major Producers of Nickel

Until the late 1960's, the mine production of nickel was geographically concentrated in a few countries. Since then there has been a marked expansion in the number of nickel producing countries. However, the ownership of nickel production is still highly concentrated and is, perhaps, the most concentrated among the major metals. The industry as a whole has a significant degree of vertical integration and is almost totally privately owned¹.

In the early 1950's, a single company, the International Nickel Company of Canada (INCO), alone controlled about 80 % of total world output. At the present time INCO operates 17 mines in Ontario and Manitoba. It also owns a few ore smelters and refineries in Canada and also refines a significant amount of production in Clydach, Wales. Currently, INCO is also participating in nickel production in Guatemala and Indonesia. INCO's dominance began to erode in the mid-1950's when it refused to participate in the US government plan to build up a stockpile of nickel under the General Services Administration. This opened the way for other companies which were assured of a market for their products because of the stockpiling program. INCO's share declined gradually to about 27 % in 1980. The technological breakthroughs in the 1960's which were discussed in the previous section were also responsible for INCO's diminished dominance in the nickel market.

The other two companies which have traditionally been producing a significant amount of nickel still account for a substantial part of the world nickel production. They are Société Métallurgique Le Nickel (SLN) and Falconbridge Nickel Mines Ltd. SLN operates mines and smelters in New Caledonia

¹ For example INCO's control starts from mining through processing and refining and extends to fabricating the metal products.

and produces nickel rondelles at Le Havre, France; it contributes about 12 % of world output. Falconbridge owns a number of mines and smelters in Canada and refines the large part of its output in Kristiansand, Norway; it provides about 6 % of total world production¹.

About 40 other companies account for the remaining world nickel production. Among them are Sherritt Gordon Mines Limited of Canada, Western Mining Corporation Limited of Australia, and Hanna Mining Co., Inc. Sherritt Gordon Mines Ltd. produced nickel from its Lynn Lake Manitoba mine up to 1977. Since then, with the closure of the mine, the company was dependent on imported concentrates, principally from Western Australia. These supplies were cut off in 1978 as the mines providing the principal feed were also closed. Subsequently arrangements were made with INCO to provide feed stocks on a long-term basis from the Thompson area².

Western Mining Corporation Limited of Australia is among the newcomers; since the start of its operation in the late 1960's this company has expanded rapidly and currently produces about 9 % of world output.

The structure of the world nickel industry, excluding centrally planned economies, is presented in table (5).

¹ Hilmy, (1979), p. 25.

² Minerals Yearbook, (1979).

Table (5) - Corporate Structure of the World Nickel Industry¹
 (% of total deliveries)

	1955	1965	1970	1974	1976
International Nickel Co. of Canada	67.1	61.1	43.9	39.1	35
Société Métallurgique Le Nickel	5.1	8.7	10.8	9.6	11.5
Falconbridge Nickel Mines Ltd.	9.4	9	7.1	6.4	6.1
Sherritt Gordon Mines Ltd.	6.5	3.3	1.9	2.1	2.1
Hanna Mining Co., Inc.	4.1	3.1	2.2	2.2	2
Western Mining Co., Inc.	-	-	3.4	7.2	8
Other Producers ²	7.8	14.8	30.7	33.4	35.3
Total	100	100	100	100	100

¹ Excluding centrally planned economies.

² Largely independent Japanese-owned mines in New Caledonia.

Among socialist economies, the Soviet Union and Cuba are the main producers of nickel. While the Cuban production of nickel has changed little during 1970's, the Soviet Union's production of nickel has grown steadily and it currently accounts for 20 % of world production. The production capacity of the Norlisk nickel complex in Siberia will be expanded by 80 % during the tenth 5-year plan, which started in 1977. This expansion will raise total Soviet capacity by 44%, from 231 000 to 310 000 tons of nickel annually and will make the Soviet Union the country with the highest production capacity. However, it is unlikely that this will affect the structure of the world nickel industry because almost the entire nickel production of East-block nations is used internally.

b) Identified World Nickel Resources and Reserves

Resources are defined as total known deposits regardless of whether or not they are minable at a profit under current economic conditions. Resource availability is essentially dynamic since the state of technology will be the crucial factor in determining what is and what is not to count as a resource at any point in time. Reserves are the proportion of identified resources that are economic to extract given current prices and costs. Large fluctuations in costs and price, specially the latter, which occur over relatively short periods, may lead to large fluctuations in the level of reserves, particularly for those countries with large marginal deposits¹.

World nickel reserves, excluding nickel associated with seabed manganese nodules, have been estimated by the US Bureau of Mines at 60 million tons for 1977, but the estimates are based on fragmentary information and are probably low². The general distribution and order of magnitude of the principal nickel reserves are given in table (6). Total identified resources are estimated at nearly 175 million tons of nickel in 1977.

¹ Hilmy, (1979), p. 21.

² Mineral Commodity Profile, (1977), p. 6.

Table (6) - Identified World Nickel Resources in 1977
(thousand tons)

	Reserves	Other Resources	Total Resources
North America:			
United States	200	14 900	15 100
Canada	<u>9 600</u>	<u>11 600</u>	<u>21 200</u>
Total	9 800	26 500	36 300
Africa:			
	2 300	6 700	9 000
Central America and Caribbeans:			
Cuba	3 400	14 200	17 600
Dominican Republic	1 100	100	1 200
Guatemala	300	900	1 200
Puerto Rico	<u>-</u>	<u>900</u>	<u>900</u>
Total	4 800	16 100	20 900
Europe:			
USSR	8 100	13 200	21 300
Oceania:			
Australia	5 600	3 200	8 800
Indonesia	7 800	6 600	14 400
New Caledonia	15 000	31 300	46 300
Philippines	<u>5 400</u>	<u>5 800</u>	<u>11 200</u>
Total	33 800	46 900	80 700
South America:			
Brazil	200	3 300	3 500
Colombia	900	600	1 500
Venezuela	<u>-</u>	<u>700</u>	<u>700</u>
Total	1 100	4 600	5 700
World Total (rounded) ¹	60 000	114 000	175 000

¹ Excludes nickel from marine sources.

c) Nickel from Marine Sources

The existence of manganese nodules has been known since they were first dredged up from the ocean by the H. M. S. Challenger expedition in 1873. Today it is well known that most of the earth's oceans contain different concentrations of nodules of varying size, composition and metal grade. However, currently only an area in the North-Central Pacific is considered for commercial exploitation. The mineral content of the nodules (dry weight) in this area is estimated to be 18 - 24 % manganese, .75 - 1.25 % nickel, .50 - 1.15 % copper and .25 - .35 % cobalt¹. Higher metal contents have been reported by the Third United Nations Conference on the Law of the Sea, namely 24 % for manganese, 1.6 % for nickel, 1.4 % for copper and .21 % for cobalt². If the latter estimates are to be believed, it implies that the richness of the nodules surpasses the metal grade of the Sudbury mines in Canada, one of the richest nickel deposits in the world, with 1.4 % of nickel and 1.2 % of copper³.

It is currently estimated that seabed mining units would need to have a capacity of at least 3 million tons of nodules per year. This would yield some 35 000 tons of nickel, 30 000 tons of copper, 5 000 tons of cobalt and 630 000 tons of manganese. Thus, nickel output of one seabed operation would be equivalent to about 5 % of the current world consumption of nickel⁴.

¹ The Future of Nickel and the Law of the Sea (1980), p. 17.

² Economic Implications of Seabed Mineral Development in the International Area, (1974), p. 28

³ Op. cit., p. 17.

⁴ The feasibility of a 3 million ton per year mining unit has not been proven yet. Smaller amounts of nodules have already been recovered from the ocean floor, but for commercial operation some parts of the equipment, the nodule collector in particular, have to be enlarged.

Whether and when seabed mining will commence depends not only upon the actual terms of the convention that may emerge from the Third United Nations Conference on the Law of the Sea (UNCLOS III), but also on the market conditions of the minerals involved. Of the four minerals that may be recovered from manganese nodules - manganese, copper, nickel, and cobalt - over half the expected revenue would come from nickel. As a result, the market for nickel is a primary determinant of the feasibility of seabed mining.

Historically, the major source of nickel has been from Canadian sulfide ore deposits, but recently the output from nickel laterite deposits have been competing with the Canadian producers. However, the process of getting nickel from laterite ores was developed when oil prices were low. With the rapidly increasing costs of energy in the 1970's, lateritic projects have lost ground to sulfide deposits in terms of cost of production. None of the recent mine smelter complexes for lateritic ores is thought to have yielded a "reasonable return" on investment¹.

Energy, at INCO's lateritic project in Guatemala, which relies totally on petroleum for its energy needs, accounts for 60 percent of total operating costs. It is estimated that a one-dollar increase in the price of a barrel of oil raises the production costs of one pound of nickel by 5 cents². Therefore, as a result of the increase in the price of oil in 1979/1980, INCO decided to stop the Guatemala nickel operation in the third quarter of 1980 and the operation remained suspended through 1981³.

¹ Boin (1980), p. 47.

² See "Remarks by J. E. Carter to the Toronto Society of Financial Analysts", (28 February 1980).

³ INCO's 1980 Annual Report.

It is currently expected that nickel from marine sources is competitive with laterite deposits¹. The same does not hold for sulfide deposits². This, however, is not the relevant comparison since new landbased nickel mines will mostly be dependent on laterite ores.

d) Secondary Sources of Nickel

Another source of nickel is from nickel scrap. There are two main sources of nickel scrap. The first is the scrap produced in fabricating plants from metal machined away in the process of manufacturing final nickel products; they have taken the form of cuttings of stainless steel, nickel alloys and ferro scrap. Such "new scrap" is consumed either directly as "run-around" scrap in plants producing superalloys and stainless steel or as "prompt industrial" scrap in the nickel smelters and refineries and steel mills³. This scrap is reused in a 6 - 8 month cycle. The second source - "old scrap" - is obtained from obsolete nickel-bearing materials with a cycle of 15 to 20 years.

Nickel consumption and production from scrap is well documented in the US. In other countries it is usually included in the statistics on refined nickel output. However, US data may to a reasonable degree indicate the scrap consumption patterns of Europe, Japan and other nickel consuming countries.

¹ For a detailed cost comparison between seabed and land-based mining of nickel see Rolf Dick (1981).

² "High grade sulfide deposits can beat ocean mining hands down". See Engineering and Mining Journal (1981), pp. 123 - 133.

³ Hilmy (1979), p. 23.

The recovery of nickel in nonferrous scrap increased fourfold from about 8 000 metric tons in 1950 to about 32 500 tons in 1972. However, the recovery of nickel from nonferrous scrap has been around 12 000 tons in the last few years. The importance of scrap as a major source of nickel can be noted by comparing the US primary nickel consumption and the scrap nickel consumption. In table (7) total nickel consumption and consumption of nickel in scrap are compared. On the average, nickel scrap accounts for about 25 % of the US nickel consumption; this share seems to be higher when shortages appear as in 1969.

e) Production Prospects and the Availability of Nickel in the Future

Given the current economic conditions in the major nickel consuming nations and the presence of a substantial unused capacity in the nickel industry one can expect that there will be no shortages of nickel in the near future. Even if the output of nickel from seabed mining does not materialize in the mid-1980's, the existence of the present idle capacity in the nickel industry and the addition of the new capacity already being underway will ensure that sufficient amounts of nickel will be available well into the 1990's¹.

Future additions to the world's nickel production capacity and their respective start up dates are listed in table (8). It can be seen that even if there is no output from seabed nodules there will be some 530 thousand tons of new production capacity. However, some of the mines in operation are marginal mines and the continuation of their operation depends on nickel prices to remain high. This is

¹ Since these capacities were installed in the second half of the 1970's, it can be assumed that the continuation of their operation depends on the price and costs of producing nickel to remain around the mid-1970 level.

Table (7) - US Primary Nickel vs. Scrap Nickel Consumption
(1000 metric tons)

	Total Nickel	Nickel Scrap	Nickel Scrap as % of Total
1964	119.8	46.2	38.6
1965	172.7	46.2	27.0
1966	264.8	57.2	21.6
1967	213.3	47.4	22.2
1968	180.4	33.2	18.4
1969	202.7	64.4	31.8
1970	202.7	44.2	21.8
1971	180.2	57.2	31.7
1972	213.5	61.2	28.7
1973	248.1	59.8	24.1
1974	257.3	58.8	22.7
1975	177.9	37.7	21.2
1976	193.4	42.6	22.0
1978	193.0	28.9	15.0
1979	218.6	40.2	18.2
1980	176.5	34.5	19.5

Source: US Bureau of Mines, Minerals Yearbook, (1979).

Table (8) Nickel Production Capacity Additions to the
1976 Level, (Thousands of tons, metal content)

	start up	1980	1985	1990
<u>Developed Countries</u>		<u>26</u>	<u>113</u>	<u>140</u>
Australia:		26	65	80
Windarra Nickel	1978/79			
Forrestania	1980			
Western Select Agnew	1980/81			
Greece:		-	18	20
Large	1981			
Yugoslavia:		-	30	40
Kavadarci	1981			
Golos	1980/81			
<u>Developing Countries</u>		<u>82</u>	<u>205</u>	<u>335</u>
Indonesia:		48	90	105
PT International Nickel	1977			
PT Pacific Nickel	1985			
Indonesia Nickel	1987			
Guatemala:		12	20	25
Eximbal	1978			
Brazil:		21	20	50
Morrs do Niguel	1978			
Columbia:		-	15	20
Cerra Matoso	1981/82			
Venezuela:				
Lomo de Hierro	1985			
Phillippines:		-	-	25
Varions	1987			
New Caledonia:		18	50	80
SLN	1980			

Table (8) - Continued

<u>Contrally Planned Economics</u>		<u>27</u>	<u>105</u>	<u>150</u>
USSR:		27	60	100
Norlisk	1980			
Cuba:		-	35	50
Punta Gorda	1982			
<u>Seabed Nodules</u>		-	<u>25</u>	<u>160</u>
Totals:				
<u>Additional Capacity</u>				
Land-Based		135	423	625
Land-Based Excluding CPE's		108	318	475
Sea Based Nodules		-	25	160
<u>Effective Capacity</u> (.85 Factor)				
Land-Based		115	360	530
Land-Based Excluding CPE's		90	270	400
Sea-Based Nodules		-	25	160

Source: Hilmy (1979), p. 74

also the case for some of the nickel laterite projects which were hard hit by recent sharp increases in the costs of energy¹.

As can be seen from table (8), most of the future increase in mine production are likely to come from the developing countries, mostly from Indonesia and New Caledonia, both of which are well endowed with economically exploitable ore.

3. Producers, Consumers and Governments Stocks of Nickel

During the 1950's, world nickel supplies, excluding centrally planned economies, exceeded consumption by 228 thousand tons². However, the market was not affected by this apparent surplus since the US General Service Administration was starting to build up stocks. In fact, about 80 % of the above surplus went into the US stockpile of nickel and the rest went mainly into producers' inventories. From 1960 to the early 1970's, the US government started to dispose of its nickel stocks in excess of its stockpile objective. Most of this disposal took place at times of shortages of nickel supplies and hence contributed to price stability. Other parts of those disposals went into producers' and consumers' stocks. But these inventory accumulations did not seem to be excessive, since the rising level of consumption necessitated additional stocks of nickel. Furthermore, the rising price of nickel and the fear of nickel shortages in the future made inventory accumulation an attractive investment.

¹ INCO's closure of the Eximbal project in Guatemala in 1980 is a good example of how the increase in energy costs can make an existing project unprofitable.

² Hilmy (1979), p. 45.

During 1975 and 1976 world production of nickel exceeded consumption by 221 thousand tons¹. This was mainly due to the producers' expectation of a quick turnaround in economic activity which did not materialize. Consumers quickly realized the market situation and started to react accordingly. Given the large stocks of nickel, the fear of short-run nickel shortages disappeared. Besides, the weakening of the market signaled lower prices in the future. Given the rising interest rates in the major consuming countries, especially in the US, inventory reductions became the optimal strategy. This caused a further reduction in deliveries of nickel and further inventory accumulation by the major producers.

The major producers reacted to this situation by lowering the official posted price of nickel and by reducing their capacity utilization. Although the official producers' price fell considerably, it still was the target of discounting and some producers were offering nickel at 5 to 10 percent below the official posted price. In early 1978 the nickel stocks amounted to about eight months' supplies compared with the normal level of two to three months.

During 1978 there was a relative improvement in producers' stocks of nickel, when consumption rose by 9 % and at the same time production declined by 23 % from the previous year. The reduction in nickel output was due to two factors: First, because of the lower nickel prices some of the marginal mines such as Sherrit Gordon Mines, Ltd., in Canada, and the Windassa sulfide mines in Australia were no longer profitable and consequently closed. Second, INCOS's Canadian mines in Sudbury had been closed since September 1978 after a labor dispute. The continuation of a strike in the Sudbury mines until June 1979 and the relative improvement in demand for nickel further reduced the

¹ For computational details refer to Appendix I.

producers' stocks of nickel. By mid-1979 producers' stock of nickel amounted to about four to five months of consumption, still about double the normal inventory requirements. Similar reductions in consumers' stocks were observed when high interest rates outweighed the benefits of holding large stocks.

At the present time there are about 29 thousand metric tons of nickel in the US strategic stockpile. Although an objective of 185 thousand tons was recently set, the US Congress has seen no immediate need to accumulate government stocks, since large commercial stocks have been available, particularly in Canada. Therefore, it is unlikely that any large stockpile purchases will be made in the near future.

The substantial increase in the price of nickel during 1979, the current slowdown in the industrialized countries and the historically high interest rates determine future changes of nickel stocks. In the immediate future the stocks of nickel could increase as a result of high prices and the current world recession. On the other hand, high interest rates and a stagnating world economy imply that efforts will be made to reduce inventories of nickel. Since the demand for nickel is not likely to pick up fast, there will be production cutbacks in the near future and/or prices will be stable or even slightly falling for the next two years.

4. Trade and Trade Barriers

Among the three major non-communist areas (Europe, Japan, North America) only Japan imposes tariffs on primary nickel. With the US 1.25 ¢/lb duty on nickel imports removed in 1965, Japan is the only major consumer of nickel which still applies

significant control on nickel imports¹. Since 1951 Japan has applied duties and allotments in order to protect and build a producing nickel industry operating smelters and refineries. During the second half of the 1950's Japan's producer nickel prices reached as high as 200 % above INCO's prevailing prices. The spread dropped to about 15 - 20 % in 1977². Also in some developing countries tariffs are applied to primary nickel imports. However, since they account for an insignificant part of the world consumption of nickel, world demand for nickel is not affected by their tariffs. In addition, there exist non-tariff barriers to the international trade in nickel. Import licences in some cases are required and in others a sales tax in one form or another is imposed³.

The communist block countries rely mainly on USSR and Cuba for their nickel imports, though small amounts of nickel are also imported from Western nations. The biggest quantities were imported by China in 1973 and 1974; they amounted to 18 and 20 thousand metric tons of nickel, respectively⁴. However, imports of East-block nations from Western countries have been less than 4000 tons of nickel in the second half of the 1970's⁵.

¹ Mohide et al. (1977), p. 179

² Ibid, p. 179.

³ Ibid, p. 179.

⁴ Ibid, p. 209.

⁵ World Metal Statistics (March 1981), p. 88.

Western countries' imports from East-block nations, on the other hand, have increased from 19 thousand metric tons in 1975 to 39.6 thousand metric tons of unwrought nickel in 1979¹.

The flow of nickel is from producing areas to refineries, which are mainly owned by the parent companies, and from refineries to the major nickel consuming countries in Europe and North America. New Caledonia and Indonesia ship ore, matte and concentrates to Japan, which also imports some concentrates from Australia. SLN's New Caledonian production is mainly shipped to France. A significant amount of INCO's new nickel output is refined in the UK, while Falconbridge's output is refined in Norway.

In the future, more processed nickel will be exported from developing countries, as almost all their projects involve processing to ferronickel. The nickel resources of these countries are laterites, relatively rich in iron. With the rapid use of ferronickel in steel making in recent years, their market share has grown to about 33 % of the world output and it is expected to grow further in the future². Furthermore, because of the anti-pollution controls recently enacted in Japan and in Canada, Japan is now promoting refining of raw materials in the countries of origin, and the Canadian production capacity has been reduced. If the demand for refined nickel rises fast, some Canadian ore might be sent to other refineries for processing. Against this background one has to remember the impact of energy costs on smelting and refining laterite ores.

¹ Also major single producers like INCO are known to have bought nickel from the Soviet Union only to resell them at the same price to their customers. World Metal Statistics (March 1981), p. 88.

² See Hilmy (1979), p. 75.

A major increase in the price of energy in the future can seriously affect the profitability of the nickel laterite projects, especially those which rely heavily on oil for their energy needs¹.

5. Historical Price Movements and Future Trends

The three main producers - INCO, SLN and Falconbridge - are known as price setters. Their posted prices are closely aligned and INCO usually takes the lead in changing the posted prices. Occasional challenges to INCO's leadership in the 1970's have always been short lived. For example, in September 1976 Falconbridge tried to lift the list price from \$ 2.20 to \$ 2.53 but was forced to reduce it to \$ 2.41 which was announced soon after by INCO. However, such a pricing policy has its own drawbacks. In the 1950's and 1960's INCO set the price, other companies sold the amount they wished, and INCO supplied the remainder of the market which was the major portion. This led to other firms gaining in size and to the erosion of INCO's share of the market segment in which nickel is sold on a non-contractual basis on short term orders. With the softening of the market in the second half of the 1970's, INCO started to change its pricing policy. It was realized that, being the supplier of last resort, most of the drop in world demand for nickel would be accounted for by reduced deliveries by INCO. This, while of little importance in the years when the market was strong, had a significant impact on INCO's share of the market when there was a reduction in the world demand for nickel. In an effort to stop

¹ INCO's Guatemala operation which was closed in 1980 is a good example of such a situation. It is estimated that the price of nickel should rise to about 450 cents per pound for the Guatemala operation to break-even and to about 620 cents per pound for that operation to yield a 10 % return. For more detail see Financial Times, November 3, 1981).

further declines in its market position INCO switched in 1975 from selling on demand to selling on a long term contract basis and started to encourage customer loyalty. Further evidence of the new policy was the announcement on July 1977 that it has rescinded the nickel price increase of October 1976 and that INCO's price will not be published, an action which was prompted by increasing inventories and a decreasing market share supplemented with sharp price discounting by other competitors.

With the rapid depletion of producer stocks in early 1979 caused by high demand, curtailed production, and the continuing work stoppage, INCO reinstated list prices in February. This action was followed by substantial price increases by other major producers in March, April and June. The June price levels, representing a 50 % increase over February levels, persisted until December when another round of price increases was announced by all major producers¹.

By far the price at which most transactions take place is the producer price. INCO's price is quoted f.o.b. refinery, Port Colbornes Ontario, or Thompson, Manitoba. Falconbridge quotes the same price f.o.b. Tharold, Ontario. The SLN price whose major output is sent from New Caledonia to France, is quoted c.i.f. at a French port, based on the Port Colborne price. The prices are quoted in United States dollars and until 1965 they included the United States tariff. These practices were followed because the United States is the principal market for Canadian refined nickel. There is also a dealers' market where very small amounts of refined products, mainly from the USSR and Cuba, are traded. But it is not an organized market since the quotations have irregular dates and give a wide range of prices.

Historically, the producer price of nickel has shown some stability, usually adjusted once a year. However, since 1974, with the rapidly rising costs of energy and inflation in the major nickel producing countries and fluctuations in the world demand for nickel, price adjustments are becoming more frequent.

¹ Minerals Yearbook, (1979).

The future trend for the costs of producing nickel is almost certain to the upward. Given the present rate of inflation in the countries which are the major producers of nickel, e. g. Canada with a current rate of inflation of 13 %, it seems very likely that the wage bills will be growing at approximately the same rate in the near future. The same holds for the costs of materials and supplies used in the nickel producing firms. Therefore, even if the future price of energy remains at its present level, which is not very likely¹, total costs of producing nickel will be rising at a rate of 4 to 7 percent, depending on the type of ore used. Of course, the future costs of energy and the rate of growth in demand for nickel will also play a major role in determining to what extent the price of nickel will rise.

In the immediate future, however, the price of nickel is expected to remain stable. This is because of the current slow-down of economic activity throughout the world, and the 60 % increase in the price of nickel which occurred as a result of the temporary shortage in 1979; the latter was perhaps too big a jump for an industry operating at about 70 % capacity. Therefore, for a year or so the price of nickel is expected to remain unchanged, allowing it to fall in real terms. In the medium run, demand conditions and energy costs are expected to increase the price moderately. The long-run trend for nickel prices, while still upwards, depends heavily on the amount of output extracted from seabed and its impact not only on the nickel market but also on markets for cobalt and manganese which can substitute nickel in a number of applications. Given the low price elasticities of consumption for all the above mentioned metals the dampening effects of the ocean mining on nickel is expected to be significant².

¹ The International Energy Agency expects a third oil crisis by the end of the 1980's. See Financial Times, October 13, 1982.

² Detailed future price projections are given in chapter IV.

Table (9) - Historical Price of Nickel

Year	US Cents per Pound
1955	65.5
56	65.16
57	74
58	74
59	74
1960	74
61	77.65
62	79.9
63	79
64	79
1965	78.68
66	78.9
67	87.77
68	95
69	105.4
1970	129
71	133
72	139.6
73	153
74	174
1975	203
76	220
77	217
78	208
79	271

Source: Weighted average of the quoted price in Metal Statistics.

III. An Econometric Model of the World Nickel Market

As it was argued before, the nickel market has not been typified as one with supply-demand equilibrium. Unanticipated changes in demand for nickel and/or nickel strikes at major producing firms such as INCO and Falconbridge have often been the main causes of market disequilibrium. Another reason for the unbalance between supply and demand in the nickel industry, which is partly related to the unanticipated changes in demand for nickel, is that the price has usually been set by INCO according to the expected future market conditions. However, when such expectations are proved to be wrong the posted price is maintained for a while, rather than letting it to respond to the market situations. Consequently, the market has frequently experienced shortages and periods of over-production.

However, this is not to say that such imbalances will be allowed to go on indefinitely. A plausible expectation is that the price setter (INCO) will respond to an imbalance in the market by adjusting its price and production in the next period¹. Therefore, the model in this study is specified according to the hypothesis that the price setter (INCO) sets the price based on what it perceives the market demand, the supply of other small producers, and the desired market inventories for nickel are going to be in the future.

¹ As an example, INCO's Annual Report in 1971 reveals that: "Through midsummer the company maintained a high rate of production in order to replenish depleted inventories and in anticipation of increasing demand. As deliveries failed to live up to expectations, the inventory accumulation became excessive and necessitated the company's program, announced in August, to curtail production. ... The further production cutbacks announced in January 1972 were designed to stop this growth."

1. INCO's Price Setting and Production Decisions

It is assumed that INCO's perceived market demand is of the form

$$D_1 = \alpha_0 + \alpha_1 \cdot E(Y_t) + \alpha_2 \cdot E\left(\frac{P_s}{P_M}, t\right) - \alpha_3 \cdot \frac{P}{P_M} + \alpha_4 \cdot Z + \Delta IN_C^* \quad (1)$$

where Y_t is the OECD index of industrial production, P_s is the U. S. price of steel, P is the U. S. producer's price of nickel, P_M is the U. S. producer price index for metals and metal products, Z is the net change in U. S. government stockpile, which is assumed to be exogenous, ΔIN_C^* is the consumers' desired change in stocks of nickel, and $E(\)$ is the expectation operator.

There are practical reasons for specifying demand for nickel as a function of price of steel and nickel in U. S.-dollars. First, U. S. firms are the biggest consumers of nickel and INCO's major customers. Second, the relevant deflator for metal prices can only be found in the U. S. The use of the OECD index of industrial production as the activity variable is justified since those countries account for 95 % of the non-communist world consumption of nickel.

The variable Z should theoretically have a unit coefficient, but to allow for the possibility that producers may regard U. S. government's purchase of nickel different from the usual demand for nickel, α_4 was introduced.

Furthermore, the aggregate supply of other small producers is specified as

$$S = \beta_0 + \beta_1 \cdot \frac{P}{P_M} + \beta_2 \cdot T - \Delta IN_S^* \quad (2)$$

where T stands for time, introduced to capture the improvements in technology and the discoveries of nickel and ΔIN_S^+ is the small producers' desired change in inventories. The price setter's net demand can be obtained by subtracting equation (2) from equation (1), or

$$ED = \gamma_0 + \gamma_1 \cdot E(Y_t) + \gamma_2 \cdot E\left(\frac{P_{S,t}}{P_M}\right) - \gamma_3 \cdot \frac{P}{P_M} + \gamma_4 \cdot Z - \gamma_5 \cdot T + \Delta IN^* \quad (3)$$

where $\gamma_0 = \alpha_0 - \beta_0$, $\gamma_1 = \alpha_1$, $\gamma_2 = \alpha_2$, $\gamma_3 = \alpha_3 + \beta_1$, $\gamma_4 = \alpha_4$, $\gamma_5 = \beta_2$, $\Delta IN^* = \Delta IN_C^* + \Delta IN_S^*$.

Equation (3) shows how much the dominant firm expects to sell. Clearly, this does not signal the production of an equal amount, unless the price setter is satisfied with its current inventories of nickel. When its inventory is excessive or short of the desired level, production of nickel is determined by

$$ED^* = ED + \Delta IN_d^* \quad (4)$$

where ΔIN_d^* is the dominant firm's desired change in stocks of nickel. Therefore, nickel production of the price setter is determined by

$$ED^* = \gamma_0 + \gamma_1 \cdot E(Y_t) + \gamma_2 \cdot E\left(\frac{P_{S,t}}{P_M}\right) - \gamma_3 \cdot \frac{P}{P_M} + \gamma_4 \cdot Z - \gamma_5 \cdot T + \Delta INT^* \quad (5)$$

where $\Delta INT^* = \Delta IN^* + \Delta IN_d^*$.

To avoid the simultaneity problem and keep the model manageable, the expected level of OECD industrial production and the price of steel are assumed to follow a first-order Markov process. Now INCO's profit function, assuming a constant average cost can be written as

$$\pi = P(\gamma_0 + \gamma_1 \cdot Y_{t-1} \dots + \Delta IN^*) - AC(\gamma_0 + \dots - \gamma_3 \cdot \frac{P}{P_M} + \dots + \Delta INT^+) \quad (6)$$

Since INCO's average cost data are not available, it is assumed that the average cost of nickel production is a linear function of the Canadian consumer price index¹, adjusted by the U. S.-dollar exchange rate, since P is measured in U. S.-dollars. Therefore

$$\pi = P(\gamma_0 + \dots - \gamma_3 \cdot \frac{P}{P_M} + \Delta IN^*) - (-a_0 + a_1 \cdot ccp) (\gamma_0 + \dots - \gamma_3 \frac{P}{P_1} + \Delta INT^*) \quad (7)$$

Maximizing equation (7) with respect to P yields

$$\frac{P}{P_M} = \frac{\gamma_0}{2\gamma_3} + \frac{\gamma_1}{2\gamma_3} \cdot Y_{t-1} + \frac{\gamma_2}{2\gamma_3} \cdot \frac{P_{s,t-1}}{P_M} + \frac{\gamma_4}{2\gamma_3} \cdot Z - \frac{\gamma_5}{2\gamma_3} \cdot T - \frac{a_0}{2\gamma_3} \cdot \frac{1}{P_M} + \frac{a_1}{2\gamma_3} \cdot \frac{ccp}{P_M} + \frac{1}{2\gamma_3} \cdot \Delta IN^* \quad (8)$$

Substituting equation (8) in (5) gives

$$ED^+ = \frac{\gamma_0}{2} + \frac{\gamma_1}{2} \cdot Y_{t-1} + \frac{\gamma_2}{2} \cdot \frac{P_{s,t-1}}{P_M} + \frac{\gamma_4}{2} \cdot Z - \frac{\gamma_5}{2} \cdot T + \frac{a_0}{2} \cdot \frac{1}{P_M} - \frac{a_1}{2} \cdot \frac{ccp}{P_M} + \Delta INT^* - \frac{1}{2} \Delta IN^* \quad (9)$$

¹ This formulation appears to be justified in the face of wage-determined price increases. In contrast to mining of laterite nickel ores, mining of INCO's sulfide ores in Canada is relatively labour intensive. Indeed, announcements of price increases by INCO frequently allude to wage settlements, which in Canada have, in recent years, been predominantly oriented at the consumer price index.

Unfortunately, both the market's desired change in inventories, ΔINT^* , and the desired change in inventories excluding INCO, ΔIN^* , are not observable. Therefore, before estimating equations (8) and (9) proxy values for these unobservable variables must be found.

2. The Market's Desired Change in Inventories of Nickel

To find an appropriate measure, it is assumed that the desired level of inventories can be written as

$$INT_t^* = C_0 + C_1 \cdot E(CNT_t) + C_2 \cdot E(P_t) - C_3 \cdot R \quad (10)$$

In this relationship, the desired level of inventories depends on the expected level of consumption in period t , the expected price of nickel in time t and the opportunity cost of holding inventories represented by the short term U. S. interest rate, R . Again, if expectations are assumed to be a first order Markov process we will have

$$INT_t^* = C_0 + C_1 \cdot CNT_{t-1} + C_2 \cdot P_{t-1} - C_3 \cdot R \quad (11)$$

In recognition of the fact that actual adjustments will only be partial, the actual adjustment will be

$$\begin{aligned} \Delta INT = INT_t - INT_{t-1} = \theta \cdot (C_0 + C_1 \cdot CNT_{t-1} + C_2 \\ \cdot P_{t-1} - C_3 \cdot R) - \theta \cdot INT_{t-1} + \epsilon \end{aligned} \quad (12)$$

where ϵ is the error term and $0 < \theta < 1$ is the adjustment coefficient. Equation (12) can be estimated by ordinary least squares and the fitted value of ΔINT can be used as a proxy for the true, but unobservable desired change in inventory, ΔINT^* ¹.

¹ The procedures used in this paper for calculation of the world stocks of nickel are described in Appendix I.

A further difficulty arises in measuring the desired change in inventory of nickel of small (non-INCO) producers and consumers, ΔIN^* . Since there are no data on individual producer and consumer inventory¹, it is assumed that the change in inventories excluding INCO, ΔIN^* , is proportional to the change in total inventories, i. e.

$$\Delta IN^* = \mu \cdot \Delta INT^*, \quad 0 < \mu < 1 \quad (13)$$

When all firms and consumers possess the same information, this assumption is not unreasonable.

Equation (9) can now be rewritten as

$$\begin{aligned} ED^* = & \frac{\gamma_1}{2} + \frac{\gamma_2}{2} Y_{t-1} + \frac{\gamma_3}{2} \frac{P_{S, t-1}}{P_M} - \frac{\gamma_4}{2} \cdot Z - \frac{\gamma_5}{2} \cdot T \\ & + \frac{a_0}{2} \cdot \frac{1}{P_M} - \frac{a_1}{2} \cdot \frac{ccP}{P} + (1 - \frac{\mu}{2}) \cdot \Delta INT^* \end{aligned} \quad (14)$$

To get a proxy value for the market's desired change in inventories, ΔINT^* , equation (12) was estimated with the results tabulated as equation A.

¹ Consumer inventories are only available in the case of the U. S.

Equation - A

The Nickel Market's Desired Change in Inventories (ΔINT)*

$$\begin{aligned} \Delta INT^* &= -46.66 + .286478 + CNT(-1) - 30.2612^* R \\ &\quad (-2.32) \quad (3.13) \quad \quad \quad (-5.7) \\ &+ 1.56385^* P(-1) - .653251^* INT(-1) \\ &\quad (4.009) \quad \quad \quad (-5.43) \end{aligned}$$

$$R^2 = .796 \quad \bar{R}^2 = .753 \quad D.W. = 2.04 \quad F = 18.5$$

Sample: 1956 - 79

where

CNT = World Consumption of Nickel
R = U. S. Short Term Interest Rate
P = U. S. Producer Price of Nickel
INT = World Stock of Nickel

The fitted values of ΔINT were subsequently used as proxies for the market's desired change in stocks of nickel.

The estimated values of the actual desired changes in stocks of nickel are presented in table (10).

Table (10) - Actual vs Desired Change in Inventory of Nickel

Year	Actual Change in Inventory 1000 M. T.	Desired Change in Inventory 1000 M. T.
1961	44.29	32.84
62	18.55	5.56
63	.62	- 15.32
64	- 12.46	- 21.8
65	- 6.56	- 9.99
1966	11.42	- 24.99
67	- 18.85	- 2.56
68	- .4	- 5.3
69	- 35.09	- 30
70	33	20
1971	92	120
72	2.55	59
73	- 6.58	- 5
74	10.06	16
75	145.7	119
1976	66.86	56
77	102.2	56
78	- 98.2	- 80
79	-121.5	- 98

3. Price Setting Equation

According to the model INCO sets the price in the way described by equation (8). However, as it was argued before, the amount of nickel used per unit of GNP or industrial production varies over the different phases of economic growth. Early stages of industrialization are usually accompanied by a sharp rise in metal (nickel) consumption per unit of GNP; this was perhaps the case during the late 1940's and in the 1950's when OECD countries were trying to catch up to the U. S. level of nickel consumption. In the more advanced phases, e. g. in the 1960's, nickel consumption growth matched that of GNP. However, in the more advanced stages, taken to be the 1970's in this study, the pattern of demand changes in favour of services using less metals, and in favour of goods with high value added and low metal (nickel) content, such as computers and electronics. Therefore, nickel consumption per unit of GNP starts to decline.

Since our estimation period runs from 1961 to 1979 it was assumed that during the 1960's nickel consumption grew more or less at the same rate as the index of industrial production in OECD countries. But in the 1970's nickel consumption per unit of industrial production tended to fall. Therefore, an additional variable ($Y_{t-1} \cdot TD$) was introduced in equation (8). TD takes the value of zero from 1961 to 1970 and from then on starts to increase by one unit each year. If our hypothesis is true, then this variable must have a negative coefficient. Indeed, this turned out to be the case. A similar variable was introduced while estimating nickel consumption of the individual OECD nations; in most cases it performed satisfactorily.

The multivariate estimates of the price equation and the equation corresponding to the nickel production of Canada are reported as equations A-1 and A-6. The price equation performs very well. All the variables have the appropriate sign and are significantly different from zero.

The elasticities of real price of nickel with respect to the OECD industrial production and the real price of steel are approximately 1 and 1.25. The elasticities with respect to the deflated average cost of production and the desired change in inventories are 2.36 and .001, respectively¹.

¹ The elasticity with respect to the average cost of production is not the true elasticity since the other component of the cost, $\frac{EXC}{P_M}$, has not been taken into account.

Equation - A1

Average Producer Price of Nickel, Deflated $\left(\frac{P}{P_M}\right)$

$$\begin{aligned} \frac{P}{P_M} = & .454942 + .0115909^* Y_{(t-1)} - .000826301^* (Y_{(t-1)})^* TD \\ & (1.63) \quad (3.67) \quad (-5.12) \\ & -.09558^* T + .000948255^* Z + 15.6363^* \left(\frac{P_S, t-1}{P_M}\right) \\ & (-3.43) \quad (3.13) \quad (4.59) \\ & + 4.10758^* \left(\frac{CCP}{P_M}\right) \cdot EXC - 313.867^* \left(\frac{EXC}{P_M}\right) + .000892684^* \\ & (4.73) \quad (6.21) \\ & \Delta INT^* + .27586^* D79 OIL \\ & (6.03) \end{aligned}$$

Log of Likelihood Function = -15.09, D. W. = 2.11, S.E.R. = .024

Sample: 1961 - 79

where

- P - Average Producer Price of Nickel
- P_M - Producer Price Index for Metals and Metal Products, 1967 = 100
- Y - OECD Index of Industrial Production, 1975 = 100
- T - Time
- Z - Change in the U. S. Government Stockpile of Nickel
- P_S - Cold Finished Steel Bar Price
- CCP - Canadian Consumer Price Index, 1975 = 100
- ΔINT^* - Desired Change in the Stocks of Nickel
- D79 OIL - Dummy for 1979 Oil Shock
- TD - Dummy for Reduced Nickel Intensity in 1970's
- EXC - Canadian Dollar Exchange Rate with U. S. Dollar

4. Demand Equations

Six intermediate use equations were estimated for the United States, the only country for which data for nickel consumption by intermediate use was available. Eight aggregate consumption equations were estimated for the United Kingdom, France, the Federal Republic of Germany, Italy, Sweden, Japan, other non-communist countries, and the centrally-planned economies. Numbers in the parantheses under the coefficients are t-statistics. Since the amount of nickel available for consumption was insufficient to meet demand from 1967 to 1969, those years were eliminated from the sample by using a dummy variable equal to one for each for those years.

a) United States Consumption of Nickel

Six intermediate use equations were estimated for the consumption of nickel in stainless steels, alloy steel, cast iron, electroplating, nonferrous alloys, and other uses. The sample period is from 1956 to 1978, and for the reason previously given observations corresponding to the years from 1967 to 1969 were eliminated from the sample.

(i) U. S. Consumption of Nickel in Stainless Steels (CUSSS)

Because chromium is a complement for nickel in the production of stainless steels the coefficient of the real price of chromite is expected to have a negative sign. The activity variable used in this equation is the U. S. production of stainless steels. The own price variable is a two-period average of the real price of nickel. The real price of other metals which act as complements in stainless steel production, such as molybdenum and aluminium, were also included; both prices had coefficients significantly different from zero.

The elasticity of the consumption of nickel in this intermediate use with respect to stainless steels production is 1.30 which is significantly different from one. As mentioned earlier, this result is due to the rising share of the 200- and 300-series in total stainless steels output. The long-run elasticity with respect to the price of nickel is -1, while the elasticity with respect to the price of molybdenum is -.309, and the elasticities of nickel consumption with respect to chromium and aluminium are -.28 and -.64, respectively. All the elasticities are reasonable in magnitude.

(ii) U. S. Consumption of Nickel in Alloy Steels (CUSALS)

The activity variable used in this equation is the total production of alloy steels in the United States. The own price variable is a three-period weighted average of the real price of nickel. Among other metals which could act as a substitute or a complement for nickel in this use only cobalt and manganese performed satisfactorily. The long-run price elasticity of nickel is -1.27 and the elasticity of nickel consumption with respect to total production of alloy steels in the U. S. is .88. This elasticity is not significantly different from one. The elasticity of nickel consumption in this category with respect to the real price of cobalt and manganese are -.20 and -.36, respectively. All the elasticities are calculated at the means and hence are approximate elasticities.

(iii) U. S. Consumption of Nickel in Cast Iron (CUSCI)

Most of the nickel use in this category is in the production of engine blocks and parts for the automotive and heavy equipment industries. Therefore, the US index of durable manufactured goods was used as the activity variable. The own price variable is a two-period average of the real price of nickel; the price of

aluminium and cobalt were also included in the equation. Since the presence of serial correlation was indicated by the Durbin-Watson statistic, this equation was estimated using the Cochrane-Orcutt iterative technique.

The long-run price elasticity of nickel consumption is -1.4 and the elasticity with respect to the activity variable is .77. The latter is due to the reduction in the size of the engines as a result of energy saving technologies. The elasticities of consumption of nickel with respect to the prices of aluminium and cobalt are -.85 and -.11, respectively.

(iv) U. S. Consumption of Nickel in Nonferrous and Other Alloys (CUSNF)

Because most of the alloys in this category are used in processing plants and electrical equipments, the US index of production of electrical machinery and the deflated value of the plant and equipment expenditures were used as the activity variables. Other related metals in this category are copper, aluminium and manganese. Therefore, real prices of these metals were used. The own price variable is a moving average of the real price of nickel. The long-run price elasticity of nickel consumption in this category is -1.91. Copper and manganese apparently are substitutes for nickel in this category, their elasticities being .63 and .41, respectively. Aluminium, on the other hand, plays a complementary role and has an elasticity of -1.03. The elasticities of nickel consumption with respect to real plant and equipment expenditures and production of electrical machinery are .63 and .41. The sum of the elasticities of the activity variables is 1.03 which is quite plausible.

Equation - A2

U. S. Consumption of Nickel in Stainless Steels Production
(CUSSS)

$$\begin{aligned}
 \text{CUSSS} = & 80.6556 - 43.7878^* \text{MAV (PR, 1)} + .0362795^* \text{SSUS} \\
 & (4.39) \quad (-5.39) \quad (-12.09) \\
 & - 45.3693^* \text{PCHR} - 8.44221^* \text{PMOLR} - 105.314^* \text{PALR} \\
 & (-3.10) \quad (-2.06) \quad (-2.11) \\
 & + .692688^* \text{D67} - 3.81587^* \text{D68} - 11.9373^* \text{D69} \\
 & (.23) \quad (-1.34) \quad (-4.05)
 \end{aligned}$$

$$R^2 = .9723 \quad \bar{R}^2 = .9564 \quad \text{D. W.} = 2.53 \quad \text{S.E.R.} = 2.60$$

where

CUSSS - Nickel Consumption in US in Stainless Steel Production

PR - Producer Price of Nickel, Deflated, $(\text{PR} = \frac{P}{P_M})$

SSUS - US Production of Stainless Steels

PCHR - Price of Chromium, Deflated, $(\text{PCHR} = \frac{\text{PCH}}{P})$

PMOLR - Price of Molybdenum, Deflated, $(\text{PMOLR} = \frac{\text{PMOL}}{P_M})$

PALR - Price of Aluminium, Deflated, $(\text{PALR} = \frac{\text{PAL}^M}{P_M})$

P_M - US Producer Price Index for Metals and Metal Products

D67 - Dummy for 1967

D68 - Dummy for 1968

D69 - Dummy for 1969

Equation - A3

US Consumption of Nickel in Alloy Steels Production (CUSALS)

$$\begin{aligned} \text{CUSALS} = & 38.9839 - 25.4711^* \text{WAV (PR, 2)} - 113.072^* \text{PCOR} \\ & (7.15) \quad (-4.85) \quad (-3.80) \\ & + .00108^* \text{USALS} - 3.6456^* \text{PMANR} - 2.067^* \text{D7} \\ & (4.58) \quad (-2.55) \quad (-1.03) \\ & - 3.3055^* \text{D68} - 2.4184^* \text{D69} \\ & (-1.65) \quad (-1.22) \end{aligned}$$

$$R^2 = .7989 \quad \bar{R}^2 = .71 \quad \text{D.W.} = 1.97 \quad \text{S.E.R.} = 1.75$$

CUSALS - US Consumption of Nickel in Alloy Steel Production
PR - Producer Price of Nickel, Deflated
USALS - US Production of Alloy Steels
PCOR - US Price of Cobalt, Deflated
PMANR - US Price of Manganese, Deflated
D67 - Dummy for 1967
D68 - Dummy for 1968
D69 - Dummy for 1969

Equation - A4

US Consumption of Nickel in Cast Iron (CUSCI)

$$\begin{aligned} \text{CUSCI} = & 7.7407 - 6.63^* \text{MAV} (\text{PR}, 1) + .04372^* \text{YDMAN} \\ & (1.48) \quad (-2.88) \quad (2.82) \\ & - 15.8062^* \text{PALR} - 7.3538^* \text{PCOR} - .2321^* \text{D67} \\ & (-1.89) \quad (-.80) \quad (-.60) \\ & - .12515^* \text{D68} - .4932^* \text{D69} \\ & (-.28) \quad (-1.20) \end{aligned}$$

$$R^2 = .8597 \quad \bar{R}^2 = .79 \quad \text{D.W.} = 2.07 \quad \text{S.E.R.} = .42 \quad \rho = .95 \quad (15.45)$$

where

- CUSCI - US Consumption of Nickel in Cast Iron
- PR - US Price of Nickel, Deflated
- YDMAN - US Production of Durable Manufactured Goods, 1967 = 100
- PALRL - US Price of Aluminium, Deflated
- PCORL - US Price of Cobalt, Deflated
- D67 - Dummy for 1967
- D68 - Dummy for 1968
- D69 - Dummy for 1969

Equation - A5

US Consumption of Nickel in Nonferrous and Other Alloys (CUSNF)

$$\begin{aligned} \text{CUSNF} = & 80.6558 - 88.4887^* \text{MAV (PR, 1)} + 27.5838^* \text{YPEQR} \\ & (5.12) \quad (-9.18) \quad (3.24) \\ & + .207771^* \text{YELM} + 71.1261^* \text{PCUR} - 177.341^* \text{PALR} \\ & (3.76) \quad (4.82) \quad (-4.34) \\ & + 8.76727^* \text{PMANR} - 5.50568^* \text{D67} - 6.12782^* \text{D68} \\ & (3.29) \quad (-1.91) \quad (-2.28) \\ & - 12.8345^* \text{D69} \\ & (-4.60) \end{aligned}$$

$$R^2 = .957 \quad \bar{R}^2 = .927 \quad \text{D.W.} = 2.42 \quad \text{S.E.R.} = 2.41$$

where

- CUSNF - US Consumption of Nickel in Nonferrous and Other Alloys
- PR - Producer Price of Nickel, Deflated
- YPEQR - US Plant and Equipment Expenditure, Deflated,
($\text{YPEQR} = \frac{\text{YPEQ}}{\text{WPUS}}$)
- YELM - US Index for Production of Electrical Machinery,
1967 = 100
- PCUR - US Price of Copper, Deflated
- PMANR - US Price of Manganese, Deflated
- PALR - US Price of Aluminium, Deflated
- D67 - Dummy for 1967
- D68 - Dummy for 1968
- D69 - Dummy for 1969

Equation - A6

US Consumption of Nickel in Electroplating (CUSEL)

$$\begin{aligned} \text{CUSEL} = & 41.2741 - 20.9188^* \text{WAV (PR, 5)} + .134625^* \text{CDMAN} \\ & (2.62) \quad (-2.37) \quad (4.18) \\ & - 77.5445^* \text{PALR} + 2.50087^* \text{PCHR} + 10.8953^* \text{PCUR} \\ & (-2.96) \quad (.19) \quad (1.20) \\ & + 8.63509^* \text{D57} - 3.88353^* \text{D58} - 4.6259^* \text{D67} \\ & (1.58) \quad (-1.01) \quad (2.06) \\ & + .116471^* \text{D68} - 5.05023^* \text{D69} \\ & (.047) \quad (2.06) \end{aligned}$$

$$R^2 = .94 \quad \bar{R}^2 = .869 \quad \text{D.W.} = 2.32 \quad \text{S.E.R.} = 1.81 \quad \rho = -.63 \quad (-3.78)$$

where

- CUSEL - US Consumption of Nickel in Electroplating
- PR - Producer Price of Nickel, Deflated
- CDMAN - US Index of Production of Consumer Durable Manufactured Goods
- PALR - US Price of Aluminium, Deflated
- PCHR - US Price of Chromite, Deflated
- PCUR - US Price of Copper, Deflated
- D57 - Dummy for 1957
- D58 - Dummy for 1958
- D67 - Dummy for 1967
- D68 - Dummy for 1968
- D69 - Dummy for 1969

Equation -A7

US Consumption of Nickel in Magnet, Chemical, Batteries,
and Other Uses (CUSCMO)

$$\begin{aligned} \text{CUSCMO} = & 7.22895 - 5.75944^* \text{WAV (PR, 3)} + .0703103^* \text{YDMAN} \\ & (.74) \quad (-.91) \quad (3.21) \\ & + 21.0164^* \text{PCUR} + .352106^* \text{PCADR} - 61.1377^* \text{PALR} \\ & (3.37) \quad (.55) \quad (-2.9) \\ & + 3.13467^* \text{PMANR} - 2.09877^* \text{D67} - .651652^* \text{D68} \\ & (3.18) \quad (-1.96) \quad (-.60) \\ & - 1.18363^* \text{D69} \\ & (-1.09) \end{aligned}$$

$$R^2 = .944 \quad \bar{R}^2 = .902 \quad \text{D.W.} = 2.44 \quad \text{S.E.R.} = .843$$

where

- CUSCMO - US Consumption of Nickel in Magnet, Chemical, Batteries and Other Uses
- PR - US Price of Nickel, Deflated
- YDMAN - US Index of Durable Manufactures
- PCUR - US Price of Copper, Deflated
- PALR - US Price of Aluminium, Deflated
- PMANR - US Price of Manganese, Deflated
- PCADR - US Price of Cadmium, Deflated
- D67 - Dummy for 1967
- D68 - Dummy for 1968
- D69 - Dummy for 1969

(v) US Consumption of Nickel in Electroplating (CUSEL)

The data in this category have some defects. According to a report by the Bureau of Mines the figures for 1957 and 1958 are not reliable. Therefore, two dummy variables, D57 and D58, were introduced to eliminate these years from the sample. Furthermore, the data before 1967 are not strictly comparable with the data after 1967 because the basis on which the data are reported was changed. The data for the periods before 1967 were collected from surveys of electroplaters, but from 1967 the Bureau of Mines began estimating consumption of nickel in this category by using the major nickel producer's reported monthly shipments to platers. A dummy variable was introduced to capture the effect of this change, but had a coefficient insignificantly different from zero.

A six-period weighted average price of nickel yielded the highest t-statistic. The activity variable used is the US index of consumer durables; the prices of aluminium, copper and chromite are used as the price of related metals. The long-run elasticity with respect to price of nickel is -1.05 and the elasticity of the activity variable is .7, which is not significantly different from 1. Chromite, aluminium and copper have the elasticities of .03, -.98 and .20, respectively.

(vi) US Consumption of Nickel in Chemical, Magnets, Batteries, and Other Uses (CUSCMO)

Nickel is used with cadmium in batteries; copper and manganese compete with nickel in chemical uses. The most appropriate activity variable seemed to be the US index of production of durable manufactures. Price of nickel has a coefficient which is not significantly different from zero. Efforts

to use different moving averages and weighted averages of the price of nickel were also unsuccessful. A four-period weighted average price of nickel yielded the highest t-statistic.

The long-run elasticity with respect to price of nickel is $-.68$, the activity variable has an elasticity of $.83$, which is not significantly different from one. The elasticities of nickel consumption in this category with respect to the prices of copper, cadmium, aluminium and manganese are $.99$, $.10$, -1.90 and $.8$, respectively.

b) Nickel Consumption of Japan

Initially, Japan's index of industrial production, Japan's production of stainless steels and a six-period weighted average of the real price of nickel were used. But the price variable had a wrong sign. The model's performance is improved when the additional variable for the reduced nickel intensity is included. Nevertheless, the price variable remained insignificant.

The elasticities of Japan's consumption of nickel with respect to the index of industrial production and production of stainless steels are $.83$ and $.37$, respectively. The long-run price elasticity of Japan's nickel consumption is $-.1$ which is certainly too low. The poor performance for the price variable can be explained by noting that the actual price paid by the consumers in Japan was much higher than the world producer price of nickel because of the country's tariffs which at some point amounted to 200 percent.

Equation - A8

Consumption of Nickel in Japan (CJA)

$$\begin{aligned} \text{CJA} = & .272365 + .0624821^* \text{SSJA} + .310404^* \text{YJA} - .0325066^* \\ & (.02) \quad (5.30) \quad (1.60) \quad (-5.43) \\ & (\text{YJA}^* \cdot \text{TD}) - 7.94655^* \text{D67} - 2.27542^* \text{D68} - 3.33407^* \text{D69} \\ & \quad (-1.67) \quad (-.45) \quad (-.62) \\ & - 1.63557^* \text{WAV} (\text{PJ}_{(-1),5}) \\ & \quad (-.36) \end{aligned}$$

$$R^2 = .9915 \quad \bar{R}^2 = .9876 \quad \text{D.W.} = 2.20 \quad \text{S.E.R.} = 4.51$$

where

- CJA - Nickel Consumption of Japan
- SSJA - Production of Stainless Steels in Japan
- JJA - Japan's Index of Industrial Production, 1975 = 100
- D67 - Dummy for 1967
- D68 - Dummy for 1968
- D69 - Dummy for 1969
- TD - 0 from 1956 to 1970; 1 in 1971 and increasing by one unit thereafter
- PJ - Price of Nickel in Japan, Deflated

c) Consumption of Nickel in the United Kingdom (CUK)

Both the British production of stainless steels and the industrial production index were used as activity variables. The price of nickel used is a six-period average of the price of nickel in the U. K. deflated by the British wholesale price index. Three dummy variables account for the nickel shortage in the years from 1967 to 1969.

All the variables, except the UK production of stainless steel, perform satisfactorily. The long-run price elasticity of nickel is -1.15 and the elasticities for the stainless steel production and the industrial production are .24 and 1.7, respectively. The elasticity of nickel consumption with respect to the production of stainless steel seems to be low, while the elasticity of industrial production is higher than expected. This can be explained by noting that the two activity variables are often correlated with each other.

d) Consumption of Nickel in the Federal Republic of Germany (CGE)

The activity variables are Germany's index of industrial production and the production of stainless steels. The price variable is a two-period average of the price of nickel deflated by Germany's wholesale price index. Three dummy variables were also introduced to capture the effect of the 1967 to 1969 nickel shortage. The equation has a very good fit and the price and activity variables have the right sign and are highly significant.

The long-run price elasticity is -.5. The activity variables' elasticities are .6 for stainless steel production and .65 for industrial output; all elasticities are calculated at the means. The sum of the two activity variables' elasticities is 1.26, which is insignificantly different from one.

Equation -A9

Consumption of Nickel in the United Kingdom (CUK)

$$\begin{aligned} \text{CUK} = & 9.57249 - 4976.30^* \text{MAV (PUK, 5)} + .564381^* \text{YUK} \\ & (2.52) \quad (-4.03) \quad (4.64) \\ & + .0369484^* \text{SSUK} - 5.10922^* \text{D67} - 5.03028^* \text{D68} \\ & (1.70) \quad (-1.92) \quad (-1.81) \\ & - 5.80603^* \text{D69} \\ & (-2.14) \end{aligned}$$

$$R^2 = .84 \quad \bar{R}^2 = .78 \quad \text{D.W.} = 1.73 \quad \text{S.E.R.} = 2.32$$

where

CUK - UK Nickel Consumption

SSUK - UK Stainless Steel Production

YUK - UK Industrial Production Index, 1975 = 100

PUK - UK Price of Nickel, Deflated

D67 - Dummy for 1967

D68 - Dummy for 1968

D69 - Dummy for 1969

Equation - A10

Nickel Consumption in the Federal Republic of Germany (CGE)

$$CGE = 7.27067 + .0555553^* SSGE + .286711^* YGE - 3.65983^*$$

(2.86) (9.10) (5.11) (-4.75)

$$MAV (PGE, 1) - .514068^* D67 + .666241^* D68 - 3.45988^* D69$$

(-.32) (.40) (-2.03)

$$R^2 = .9935 \quad \bar{R}^2 = .9911 \quad D.W. = 1.51 \quad S. E. R. = 1.55$$

where

CGE - Nickel Consumption in the Federal Republic of Germany

SSGE - Stainless Steel Production in the Federal Republic of Germany

YGE - Index of Industrial Production, Federal Republic of Germany, 1975 = 100

PGE - Price of Nickel in the Federal Republic of Germany, Deflated,

D67 - Dummy for 1967

D68 - Dummy for 1968

D69 - Dummy for 1969

Equation - A11

Consumption of Nickel in Sweden (CSW)

$$\begin{aligned} \text{CSW} = & -2.78986 + .0634109^* \text{SSSW} - .987059^* \text{D67} - 2.90396^* \text{D68} \\ & (-4.73) \quad (33.13) \quad (-.88) \quad (-2.57) \\ & - 4.38195^* \text{D69} \\ & (-3.87) \end{aligned}$$

$$R^2 = .9839 \quad \bar{R}^2 = .98 \quad \text{D.W.} = 1.557 \quad \text{S.E.R.} = 1.09$$

Where

CSW - Swedish Consumption of Nickel

SSSW - Swedish Production of Stainless Steel

D67 - Dummy for 1967

D68 - Dummy for 1968

D69 - Dummy for 1969

e) Consumption of Nickel in Sweden (CSW)

The equation which is reported only contains the Swedish production of stainless steels and three dummy variables. The Swedish index of industrial production and the Swedish price of nickel both performed poorly and hence were dropped from the equation. Nevertheless, the fit of the equation is very good. The elasticity of nickel consumption with respect to production of stainless steel is 1.19, which is reasonable.

f) Consumption of Nickel in France (CFR)

Initially France's index of industrial production, stainless steel production and a four-period weighted average of the real price of nickel were used. But both industrial production and price of nickel had a coefficient insignificantly different from zero. However, once another variable which captures the reduced nickel intensity of the French industrial production in 1970's is introduced, both the new variable and the price of nickel became significant.

The long-run price elasticity of nickel consumption in France is approximately $-.8$ and the elasticities of the consumption of nickel with respect to industrial production and the production of stainless steel are $.73$ and $.33$, respectively. The sum of the elasticities is 1.06 which is quite plausible.

g) Consumption of Nickel in Italy (CIT)

The price of nickel in this equation had consistently a positive and significant sign and was therefore suppressed. Italy's production of stainless steel and index of industrial production were used as activity variables. Once again, the index of industrial production performs poorly unless another variable which captures the reduced nickel intensity in the 1970's is included.

Equation - A12

Nickel Consumption in France (CFR)

$$\begin{aligned} \text{CFR} = & 11.863 - 250.772^* \text{WAV} (\text{PFR}_{(-1)}, 3) + .0554327^* \text{SSFR} \\ & (2.16) \quad (-2.15) \quad (3.00) \\ & + .204236^* \text{YFR} - .00883886^* (\text{YFR}^* \cdot \text{TD}) - 1.9164^* \text{D67} \\ & (2.36) \quad (-1.34) \quad (-.7) \\ & + .739705^* \text{D68} - 2.06199^* \text{D69} \\ & (.26) \quad (-.69) \end{aligned}$$

$$R^2 = .9615 \quad \bar{R}^2 = .9435 \quad \text{D.W.} = 1.99 \quad \text{S.E.R.} = 2.31$$

where

- CFR - Consumption of Nickel in France
- SSFR - Production of Stainless Steel in France
- PFR - Price of Nickel in France, Deflated
- YFR - French Index of Industrial Production, 1975 = 100
- D67 - Dummy for 1967
- D68 - Dummy for 1968
- D69 - Dummy for 1969
- TD - Dummy Variable Equal to zero from 1956 to 1970, and 1 in 1971, 2 in 1972 and so on.

Equation - A13

Nickel Consumption in Italy (CIT)

$$\begin{aligned} \text{CIT} = & -2.69958 + .0465391^* \text{SSIT} + .119629^* \text{YIT} - .00828892^* \\ & (-1.88) \quad (3.56) \quad (2.66) \quad (-3.45) \\ & (\text{YIT}^* \cdot \text{TD}) - 1.765^* \text{D67} - .432563^* \text{D68} - 1.409^* \text{D69} \\ & (-1.3) \quad (-.32) \quad (-1.1) \end{aligned}$$

$$R^2 = .9825 \quad \bar{R}^2 = .9759 \quad \text{D.W.} = 1.388 \quad \text{S.E.R.} = 1.13$$

where

CIT - Nickel Consumption in Italy

SSIT - Stainless Steel Production in Italy

YIT - Italy's Index of Industrial Production, 1975 = 100

D67 - Dummy for 1967

D68 - Dummy for 1968

D69 - Dummy for 1969

TD - 0 from 1956 to 1970 and increasing by one unit in each period thereafter

The elasticity of stainless steel production is approximately .62 and the elasticity of consumption of nickel with respect to the index of industrial production is .68. The sum of the elasticities of the two activity variables is 1.30; that the nickel intensity variable has an elasticity of -.13, making the real sum of the elasticities approximately equal to 1.17.

h) Consumption of Nickel in Other Nations (CRW)

The activity variable used is the nickel consumption of the major western consumers of nickel. A trend dummy was added for the argument that these other nations are in early stages of industrialization and therefore the rate of increase in their consumption of nickel is usually above the nations whose consumption of nickel was used as the activity variable. A two-period average of the real price of nickel was also used as the price variable. The performance of the equation is very good. All the variables have the correct sign and are significantly different from zero.

The long-run price elasticity of nickel consumption is -1.22 and the elasticity of nickel with respect to the nickel consumption of the major consumers is .62¹. The Durbin-Watson statistic indicated the presence of serial correlation, therefore the equation was estimated using the Cochrane-Orcutt iterative technique. The estimate of the first-order serial correlation (ρ) and its t-statistic is also reported.

¹ The long-run price elasticity was calculated considering the impact of price changes on CMAJ, too.

Equation - A14

Consumption of Nickel in Other Nations (CRW)

$$\text{CRW} = -11.712 + .692792^* \text{CMAJ} + 3.31072^* \text{T} - 25.7875^* \text{MAV (PR, 1)}$$

(-.86) (6.81) (6.15) (-2.45)

$$R^2 = .989 \quad \bar{R}^2 = .9876 \quad \text{D.W.} = 1.86 \quad \text{S.E.R.} = 2.07$$

$$\rho = .86$$

(8.12)

where

CRW - Nickel Consumption of Other Nations

CMAJ - Nickel Consumption of Major Consumers of Nickel

T - Time

PR - US Price of Nickel, Deflated

The weighted long-run price elasticities of nickel consumption in Westblock nations are presented in table (11). All the elasticities are calculated at the mean and therefore are approximate elasticities. In table (12) the effect of the nickel shortage from 1967 to 1969 on the nickel consumption of the major nickel consuming nations was estimated from the dummy variables included in the demand equations. Since all these demand equations were estimated in linear form, the coefficients of the dummies measure the actual amount by which the consumption fell short of demand.

For consumption of nickel by end-uses in the United States it is indicated that the severity of nickel shortage was more pronounced in 1969, with nickel consumption in stainless steels and nonferrous category accounting for 75 % of the shortage. The apparent surplus of nickel in the electroplating category can be explained by noting that the data in this category are shipments to platers which include changes in the stocks of platers. Due to difficulties in obtaining nickel in 1966 platers probably rebuilt their stock in 1967. The apparent excess in 1967 is a result of additional stocks held by electroplaters. Among other major nickel consuming countries France and Italy seem to have experienced little difficulties in obtaining nickel, while the UK and Japan had to cutback consumption significantly. The nickel shortage was noticeable in Germany only in 1969, and in Sweden the nickel shortage increased from about one thousand metric tons in 1967 to about 4.4 thousand tons in 1969.

Table (11) Weighted Price Elasticity of Nickel Consumption

	Elasticity	Weight ¹
<u>US</u>		
Stainless Steel	-1	54.98
Alloy Steel	-1.27	15.61
Cast Iron	-1.4	3.89
Electroplating	-1.05	24.84
Non-Ferrous	-1.91	56.6
Others	-.68	8.31
		<hr/>
Total	-1.24	164.2
<u>Other Countries</u>		
U. K.	-1.15	32
France	-.8	35.5
Germany	-.5	67.4
Italy	0	24.5
Sweden	0	21
Japan	-.1*	99
		<hr/>
Total	-.4	279.5
<u>Other Non-Communist Countries</u>	-1.22	72.7
Total Non-Communist	-.77	516.2

¹ 1978 consumption figures, in thousands of metric tons.

* The elasticity of Japanese consumption of nickel is certainly too low. This is the main reason for the low elasticity for total non-communist consumption.

Table (12) Estimates of Nickel Shortage 1967 - 1969
(Thousand metric Tons)

	1967	1968	1969
United States			
Stainless Steels	- .69	3.81	11.93
Alloy Steel	2.04	3.3	2.41
Cast Iron	.23	.1	.49
Non-Ferrous Alloys	5.5	6.12	12.83
Electroplating	-4.6	- .11	5.05
Others	2.1	.65	1.19
Total	4.50	13.9	33.9
U. K.	5.1	5.03	5.08
Japan	7.94	2.27	3.3
Germany	.51	- .66	3.46
Sweden	.99	2.9	4.38
France	1.91	- .74	2.06
Italy	1.76	.43	1.41
Total	23.7	24.1	53.6

5. Supply Equations

Seven production equations were estimated. These are: nickel production of Canada, other American nations, Europe, Asia, Oceania, Africa, and centrally planned economies. Except for the nickel production of Canada, all the production equations were assumed to have a long-run form of

$$Q_L = \beta_0 + \beta_1 \cdot PR - \beta_2 \cdot \Delta INT_{(-1)} \quad (15)$$

Now, since production adjustments will be partial in the short-run, the observed values of production were estimated by

$$Q_S = \lambda \cdot (\beta_0 + \beta_1 \cdot PR - \beta_2 \cdot \Delta INT_{(-1)}) + \lambda \cdot Q_{S,t-1} \quad (16)$$

In the case of centrally planned economies only the lagged dependent variable performed satisfactorily. Different dummy variables are also used for strikes, political upheavels, and other influences. The change in the world stocks of nickel in the last period, $\Delta INT_{(-1)}$, presumably gives a signal to the producers that the current period's consumption will be partially satisfied by past inventories and hence induces them to reduce the current period's output.

Production data represent the estimated nickel content of the produced ore; the same applies to the change in the world stocks of nickel.

a) Nickel Production of Canada (QNC)

Since there are no separate data for the nickel production of INCO, Falconbridge and Sherrit Gordon, nickel production of Canada was used to estimate equation A 16. In addition, four

dummy variables were included to capture the impact of strikes in 1969, 1975, 1978 and in 1979. On statistical grounds, the performance of the model is satisfactory. All the variables, except the Canadian consumer price index, have the right sign and only the price of steel is insignificant.

In fact a positive sign for the cost variable can be understood by noting that an increase in cost causes INCO to raise the price, but the kind of mark-up pricing implicit in this model makes the price increases to be proportionally higher than the increase in cost. This may cause other Canadian producers to increase their production and hence distort the impact of the rise in the cost of production.

The elasticity of nickel production of Canada with respect to the OECD index of industrial production is 1.25 and the elasticity with respect to the desired change in inventories is .007.

This elasticity might, at first glance, seem to be too low. However, notice that 200 and 300 percent changes from year to year in this variable is not uncommon. The elasticity of nickel production of Canada with respect to the real price of steel is .23.

b) Nickel Production of Other American Countries (AMR)

The variables used in this equations are the US real price of nickel, the lagged value of the change in the world's stock of nickel and the production of nickel of these countries in the last period. A dummy variable was also included to capture the shift in the supply of nickel due to the start of Dominican Republic's

nickel production in 1972¹.

The model's performance is very good. All the variables have the correct sign and are significantly different from zero at the 1 % level. The short-run price elasticity of nickel production is .9 and the long-run price elasticity is 1.2.

c) Nickel Production of Oceania (OCNR)

The US price of nickel deflated by the producer index of metals and metal products, the lagged value of the change in the world's stocks of nickel and the lagged values of the dependent variable were used as explanatory variables. Two dummy variables, D62 and D71, were introduced to capture the effect of the strike at SLN in 1962 and the closing down of the operation for modernization in 1971. The short-run and the long-run price elasticities are 1.04 and 5.5 respectively.

d) Nickel Production of African Nations (AFR)

As before, the US deflated price of nickel, the change in the world's inventories of nickel in the last period, and the African production of nickel in the last period are used as the explanatory variables. Since nickel production in South Africa is a by-product of platinum production, the South African production of platinum was also included as an activity variable. The short-run and long-run price elasticities are respectively .356 and 1.3. The elasticity of nickel production of Africa with respect to South African production of platinum is .29.

¹ The reader may wonder why at the theoretical level a time trend variable was assumed to capture the effect of the start of new nickel production operation, but at the empirical level dummy variables such as D72 are used. We should remember that these two are not inconsistent with each other. That is, while individual supply of nickel may jump with the beginning of a new operation, when aggregated the effect of these shifts, if they are evenly spread, can be approximated by a time-trend variable.

Equation - A16

Nickel Production of Canada (QNC)

$$\begin{aligned}
 \text{QNC} = & 445.37 + 3.28314^* Y_{t-1} - .191802^* (Y_{t-1}^* \text{TD}) - 22.4558^* T \\
 & (6.09) \quad (4.28) \quad (-4.75) \quad (-3.22) \\
 & + .24386^* Z + 619.833^* \left(\frac{P_{S,t-1}}{P_M} \right) + 545.596^* \left(\frac{\text{EXC} \cdot \text{CCP}}{P_M} \right) \\
 & (3.47) \quad (.766) \quad (2.32) \\
 & - 60007.6^* \left(\frac{\text{EXC}}{P_M} \right) + .148335^* (\Delta \text{INT}^*) - 64.66^* \text{D69} - 42.38^* \text{D75} \\
 & (-3.22) \quad (3.22) \quad (-9.30) \quad (-5.4) \\
 & - 77^* \text{D78} - 48.18^* \text{D79} \\
 & (-6.79) \quad (-2.90)
 \end{aligned}$$

D.W. = 2.35 S.E.R. = 5.70

Sample: 61 - 79

where

- Y - OECD Index of Industrial Production
- TD - Dummy Equal to zero from 1961 to 1970, equal to 1 in 1971, and thereafter increasing yearly by one unit
- T - Time
- Z - Change in the US Government Stockpile of Nickel
- EXC - Canadian - US Dollar Exchange Rate
- P_S - Cold Finished Steel Bar Price
- P_M - US Producer Index for Metals and Metal Products
- CCP - Canadian Consumer Price Index, 1975 = 100
- ΔINT^* - Desired Change in the World Stocks of Nickel
- D69 - Dummy for 1969 Strike
- D75 - Dummy for 1975 Strike
- D78 - Dummy for 1978 Strike
- D79 - Dummy for 1979 Strike

Equation - A17

Nickel Production of Other American Nations (AMR)

$$\begin{aligned} \text{AMR} = & - 8.51903 + 20.9544^* \text{PR} + .247434^* \text{AMR}_{(-1)} + 19.6973^* \text{D2} \\ & (-2.43) \quad (5.16) \quad (3.66) \quad (9.78) \\ & - .0428833^* \Delta \text{INT}_{(-1)} \\ & (-4.97) \end{aligned}$$

$$R^2 = .985 \quad \bar{R}^2 = .982 \quad \text{D.W.} = 2.106 \quad \text{S.E.R.} = 1.92$$

Sample: 1956 - 1979

where

AMR - Nickel Production of Other American Nations

PR - US Price of Nickel, Deflated

D2 - Dummy Variable for the Start of the Dominican Republic's Production

ΔINT - Change in the World Stocks of Nickel

Equation - A18

Nickel Production of Oceania (OCNR)

$$\begin{aligned} \text{OCNR} = & - 71.5440 + 104.017^* \text{PR} + .822703^* \text{OCNR}_{(-1)} \\ & (-2.74) \quad (3.10) \quad (10.66) \\ & - .177592^* \Delta \text{INT}_{(-1)} - 20.3288^* \text{D62} - 13.9436^* \text{D71} \\ & (-3.12) \quad (-1.65) \quad (-1.71) \end{aligned}$$

$$R^2 = .9732 \quad \bar{R}^2 = .9658 \quad \text{D.W.} = 1.37 \quad \text{S.E.R.} = 11.59$$

Sample: 1956 - 1979

where

OCNR - Nickel Production of Oceania

PR - US Price of Nickel, Deflated

ΔINT - Change in the World Stocks of Nickel

D62 - Dummy for 1962

D71 - Dummy for 1971

Equation - A19

Nickel Production of Asia (ASIR)

$$\begin{aligned} \text{ASIR} = & - 69.2347 + 24.2718^* \text{PR} + .314764^* \text{ASIR}_{(-1)} \\ & (-2.65) \quad (2.95) \quad (2.44) \\ & + 20.0231^* \text{D7} + 2.75047^* \text{T} \\ & (8.33) \quad (1.96) \end{aligned}$$

$$R^2 = .9925 \quad \bar{R}^2 = .99 \quad \text{D.W.} = 1.58 \quad \text{S.E.R.} = 1.94$$

$$\rho = .88 \\ (7.89)$$

Sample: 63 - 79

where

ASIR - Nickel Production of Asia

PR - US Price of Nickel, Deflated

T - Time

D7 - Dummy for the Beginning of Indonesian Operation

e) Nickel Production of Asia (ASIR)

The real price of nickel, the lagged value of Asian production of nickel and a time trend variable were included as independent variable in this case. A dummy variable, D7, was also used to capture the shift in Asian supply of nickel as a result of the start of the Indonesian nickel operation.

This equation was estimated using the Cochran-Orcutt iterative technique. The price elasticity of nickel production is 1.28 in the short-run and 1.8 in the long-run.

f) Nickel Production of Europe (EUOR)

In this equation, the real price of nickel, a time trend variable and the lagged nickel production of Europa were used as explanatory variables. The model's performance is good; all the variables have the expected sign and are significantly different from zero. The short-run and long-run price elasticities are .6 and 2, respectively. A dummy variable, D77, was also introduced to capture the effect of a 3-month strike at the nickel mines in Greece in 1977.

g) Nickel Production of Eastblock Nations (EBTR)

Almost all the variation of the dependent variable is explained by its lagged value. A dummy variable was also introduced to capture the impact of the Cuban revolution on the production of Eastblock nations.

Equation - A20

Nickel Production of African Nations (AFR)

$$\begin{aligned} \text{AFR} = & - 8.50456 + 8.98973^* \text{PR} + .723803^* \text{AFR}_{(-1)} \\ & (-2.75) \quad (2.35) \quad (6.96) \\ & + .00559335^* \text{QPLA} - .0151124^* \Delta \text{INT}_{(-1)} \\ & (3.16) \quad (-1.31) \end{aligned}$$

$$R^2 = .9887 \quad \bar{R}^2 = .9859 \quad \text{D.W.} = 2.21 \quad \text{S.E.R.} = 2.29$$

$$\rho = -.63 \\ (-3.76)$$

Sample: 59 - 79

where

- PR - US Price of Nickel, Deflated
- AFR - Nickel Production of African Nations
- QPLA - South African Production of Platinum
- ΔINT - Change in the World Stocks of Nickel

Equation - A21

Nickel Production of Europe (EUOR)

$$\begin{aligned} \text{EUOR} = & - 7.2286 + 6.81115^* \text{PR} + .708226^* \text{EUOR}_{(-1)} \\ & (-2.53) \quad (2.05) \quad (7.18) \\ & + .359602^* \text{T} - 7.80890^* \text{D77} \\ & (3.31) \quad (-5.58) \end{aligned}$$

$$R^2 = .9838 \quad \bar{R}^2 = .9798 \quad \text{D.W.} = 2.01 \quad \text{S.E.R.} = 1.18$$

$$\rho = -.20 \\ (-.97)$$

Sample: 59 - 79

where

- EUOR - Nickel Production of Europe
- PR - US Price of Nickel, Deflated
- T - Time
- D77 - Dummy for a Strike in 1977

Equation - A22

Nickel Production of Eastblock Nations (EBTR)

$$\text{EBTR} = 8.86734 + .975067^* \text{EBTR}_{(-1)} - 6.01349^* \text{D6}$$

(2.40) (32.27) (-1.76)

$$R^2 = .9855 \quad \bar{R}^2 = .9841 \quad \text{D.W.} = 1.70 \quad \text{S.E.R.} = 4.8$$

Sample: 56 - 79

where

EBTR - Nickel Production of Eastblock Nations

D6 - Dummy Variable for Cuban Revolution

6. Closing the Model

Several identities are required to express the real price of nickel which is given in US-dollars in other major consuming nations' currencies. In general, the producer price of nickel is adjusted by the U.S.-dollar exchange rate against the currency of the country in question and then divided by the wholesale price index of that country. The U.S.-dollar price of nickel, net of the U.S. tariff, is used in calculating the foreign price of nickel. However, for U.S. consumption the tariff is included in the producers' price of nickel.

Other identities are needed for calculating the US consumption of nickel, the nickel consumption of major consuming nations, the world consumption of nickel, the world production of nickel, the changes in the world stocks of nickel, and the world stocks of nickel. These identities are listed in the following pages.

I.1 Nickel Price, Current Dollars (P)

$$P = \frac{P}{P_M} \times P_M$$

P = Nickel Price, net of tariff, in Current Dollars

P_M = U.S. Producers Wholesale Price Index for Metals and Metal Products

I.2 Nickel Price in UK, Deflated (PUK)

$$PUK = P/EXUK/WPUK$$

EXUK = U.S.-Dollar Exchange Rate with the British Pound

WPUK = U.K. Wholesale Price Index

I.3 Nickel Price in France, Deflated (PFR)

$$PFR = P/EXFR/WPFR$$

EXFR = U.S. Dollar Exchange Rate with the French Franc

WPFR = French Wholesale Price Index

I.4 Nickel Price in Germany, Deflated (PGE)

$$PGE = P \times EXGE/WPFR$$

EXGE = D-Mark Exchange Rate with

WPGE = German Wholesale Price Index

I.5 Nickel Price in Japan, Deflated (PJA)

$$PJA = P/EXJA/WPJA$$

EXJA = U.S. Dollar Exchange Rate with the Japanese Yen

WPJA = Japanese Wholesale Price Index

I.6 U.S. Total Consumption of Nickel (CUST)

$$CUST = CUSSS + CUSAS + CUSCI + CUSNF + CUSEL \\ + CUSCMO + RESI$$

CUSSS = U.S. Consumption of Nickel in Stainless Steels

CUSAS = U.S. Consumption of Nickel in Alloy Steel

CUSCI = U.S. Consumption of Nickel in Cast Iron

CUSNF = U.S. Consumption of Nickel in Nonferrous Alloys

CUSEL = U.S. Consumption of Nickel in Electroplating

CUSCMO = U.S. Consumption of Nickel in Chemical, Magnet
and other Uses

RESI = Residuals, an exogenous amount introduced
because in some years U.S. consumption by end-
uses does not add up to total consumption.

I.7 Nickel Consumption of Major Consuming Nations (CMAJ)

$$\text{CMAJ} = \text{CUST} + \text{CUK} + \text{CFR} + \text{CGE} + \text{CSW} + \text{CIT} + \text{CJA}$$

CUST = U.S. Total Consumption of Nickel

CUK = U.K Consumption of Nickel

CFR = French Consumption of Nickel

CGE = German Consumption of Nickel

CSW = Swedish Consumption of Nickel

CIT = Italian Consumption of Nickel

CJA = Japanese Consumption of Nickel

I.8 World Consumption of Nickel (CNT)

$$\text{CNT} = \text{CMAJ} + \text{CRW} + \text{CSU}$$

CMAJ = Nickel Consumption of the Major Consumers of Nickel

CRW = Nickel Consumption of other Western Nations

CSU = Nickel Consumption of East Block Nations

I.9 World Refined Production of Nickel (QNW)

$$\text{QNW} = \text{QNC} + \text{AMR} + \text{EUOR} + \text{AFR} + \text{ASIR} + \text{OCNR} + \text{EBTR}$$

QNC = Nickel Production of Canada

AMR = Nickel Production of Other American Nations

EUOR = Nickel Production of European Nations

AFR = Nickel Production of African Nations

ASIR = Nickel Production of Asian Nations

OCNR = Nickel Production of Oceania

EBTR = Nickel Production of East-Block Nations

I.10 Change in the World Stocks of Nickel (ΔINT)

$$\Delta\text{INT} = \text{QNW} - \text{CNT} - \text{Z}$$

QNW = World Refined Nickel Output

CNT = World Consumption of Nickel

Z = Change in the U.S. Government Stockpile

I.11 World Stocks of Nickel (INT)

$$\text{INT} = \text{INT} (-1) + \Delta\text{INT} (-1)$$

IV. Model Simulations

The present model can be used in a number of ways to study the impact of future exogenous changes in the nickel market. For example, one can study the effect of the imposition of a new tariff by the US government, or, alternatively, the impact of disposing or stockpiling of nickel by the US government. Other exogenous shocks to the supply side of the model, such as the start of seabed mining or a major strike at one of the major producers of nickel can also be investigated. Of course, one could only be interested in forecasting future consumption in different end-uses or the future production of nickel, without any concern for future exogenous changes. Finally, it might be of some interest to investigate what will happen if the structure of the model is altered, e. g. if the nickel market becomes more competitive.

One of the main concerns in simulating a system of supply and demand equations is to watch the forecasts of supply and demand to see whether they are plausible. If not, the usual strategy is to change the forecasts of some of the exogenous variables. One of the advantages of the present model is that it allows consumption to differ from production by letting inventories to be changed. However, one can not accept the forecasts of future consumption to be significantly different from production for an extended period of time. Though some increase in inventories is needed for smooth operation as world production and consumption of nickel get larger and larger over time. The possibility of disequilibrium prevailing for a long time has, to a large extent, been averted in this model by allowing inventory changes to act as an equilibrating mechanism to close the gap between future production and consumption of nickel. For instance, if an unanticipated increase in demand causes consumption in one period to exceed production

in that period, inventories will be reduced to satisfy the current excess demand. The increased consumption in that period and the reduced stocks will, in the next period, increase the price setter's desired inventory level. Therefore, the price leader reacts by announcing higher prices and increasing its own production. On the one hand, the higher prices just announced and the reduced stocks of nickel will induce other firms to increase nickel production, but on the other hand, the increase in the price of nickel is certain to reduce the amount of nickel demanded.

The above mentioned mechanism should be strong enough to guarantee a reasonable performance by the present model. Of course, there are limits within which stocks can be reduced. Inventories, for example, can not be completely depleted since a minimum amount of stocks must always be held for smooth operation. If such an unlikely situation, given the present stocks of nickel and the industry's idle capacity, happens then rationing will be implemented.

Among all possible simulations we intend to investigate the future of the nickel industry under:

1. No exogenous change in the future,
2. A stockpiling program by the US government
and
3. The start of seabed mining in 1988.

However, values of the exogenous variables must be supplied to the simulation program before forecasting. Forecasts of the exogenous variables in the model appear in Appendix III. In general, the most recent information and historical growth rates were combined to obtain the forecast values of the activity and price variables.

Before presenting the simulation results a few important points must be noted. First, both Cuba and the Soviet Union have recently added significantly to their nickel production capacities. To allow for this it was assumed that the Soviet-block nations' output of nickel will grow by an additional six thousand tons of nickel throughout the simulation period, e. g. the dummy variable D6 was given a -1 value. Second, the TD variable was allowed to grow at a slower pace, because otherwise it would overpower the positive effect of the increase in the OECD industrial production on the world demand for nickel. Finally, the sharp increase in the costs of energy in 1979 - 80 has certainly reduced the competitiveness of the nickel laterite producers and hence reduced their output of nickel. Other producers of nickel, Canadian producers in particular, are now in a better competitive position. To allow for the reduced output from nickel laterite mines the production of Australia and New Caledonia was reduced by about 40 thousand tons in 1980, about 20 thousand tons in 1981, and 10 thousand tons in 1982. The nickel production of American nations was also reduced as a result of the sharp increase in the price of oil in 1979/80.

However, nickel production of Canada was not allowed to grow in 1980 and 1981 due to the introduction of the anti-pollution legislation which has reduced Canadian production capacity. Instead, it was assumed that the increase in output will gradually start in 1982, after the introduction of anti-pollution technologies.

1. Forecasts of the Endogenous Variables Without Any Exogenous Supply or Demand Changes

In this section, some brief comments on our forecasts will be given. First, previous forecasts of the world consumption of nickel in 1985, e. g. the United Nations' forecasts of 950 thousand tons are about 10 % higher than what our model is predicting. This should not be a surprise to the reader because of the current recession in the industrialized countries with little hope for a rapid recovery. The 1980 - 81 recession came soon after nickel prices were significantly raised in 1979 - 80. Therefore, it will take some time before the 1979 level of nickel consumption can again be reached.

Second, if Canadian producers keep on playing their price leadership role they will lose more of their market share to other competitors and, consequently, Canadian nickel production will fall moderately. However, it should be emphasized that if energy costs go up in the future this will hurt particularly non-Canadian nickel producers. As a result, the reduction in nickel output will manifest itself in the reduced output of these producers.

Finally, the values of the endogenous variables are calculated on the assumption that the new nickel production capacities, presented in table (8), do not start in 1985 because of the increase in energy costs in 1979 and 1980. If we allowed the output of all the newly planned capacities to enter the market the impact will be to reduce the price of nickel. The increase in output will be 270 thousand tons, excluding the centrally planned economies' increased nickel output, which amounts to about 40 % of the increase in the nickel output of Western economies. Clearly, this amount of

Table (13) - Forecasts of the Future Price, Consumption and Output of Nickel from Land-Based Sources without any Exogenous Change *

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
P	341.1	348.8	358.9	378.8	405.5	434	466.3	496.9	554.2	616
P/PM	1.19	1.15	1.12	1.11	1.12	1.12	1.15	1.15	1.2	1.23
QNC	197.7	187.4	181.5	181.4	185.6	191.5	197.8	195.7	200.4	205.6
AMR	32.7	32.9	41.3	43.8	45	45.5	46.4	46.5	48.1	49
OCNR	159.2	156.3	157.2	169.9	183.2	194.7	207.8	218.3	234.3	249.9
ASIR	68.5	72	74.9	78.4	82.6	86.6	91.3	95.6	100.9	105.6
AFR	65.1	68.3	70.9	73.7	76.9	80	83.2	86	89.2	92.3
EUOR	25.7	28.2	30.1	31.75	33.3	34.8	36.4	37.9	39.7	41.5
EBTR	189.9	200	210	219.6	229	238.2	247.2	255.9	264.4	272.2
QNW	739	745.5	766.1	798.7	835.8	871.7	910.3	936.2	977.2	1017.2
CUSSS	51	49.9	54	58.4	62.5	67.1	70.7	74.5	78.3	81.7
CUSALS	16	17.9	19.5	21.2	22	22.5	22.8	22.9	23.1	23
CUSCI	2.23	1.86	2.36	2.76	2.98	3.33	3.62	4	4.33	4.61
CUSNF	50.2	39.3	45.3	50.1	52.4	55	57.9	61	63.4	64.9
CUSEL	23.4	22.5	22.5	22.3	22.5	23.5	24.5	25.5	26.5	27.7
CUSCMO	10.1	7.22	7.13	7.13	7.31	7.65	8.1	8.79	9.54	10.1
CUST	153.1	138.9	150.9	162	169.7	179.1	187.7	196.8	205.2	212.2
CJA	113.5	114.5	118.8	129	141.1	152.9	157.5	165.1	173.2	184.3
CUK	35	32.7	35.8	39	40.8	43.4	45.2	47.4	50.2	52.1
CGE	68.6	66.7	68.3	73.6	78.1	81.7	85.8	89.5	93.1	96.7
CSW	19.4	20	20.6	21.6	22.5	23.8	25.1	26.3	27.9	28.9
CIT	24.9	24.7	26.3	27.3	28.5	29.7	31	32.3	33.7	35
CFR	38.5	38	37.8	36.2	36.1	38	40.5	43	45.6	47.2
CMAJ	453.2	435.8	458.7	488.9	517.2	549	573	600.7	629	656
CRW	73.6	74.2	80	86	91.2	96.5	101.2	106.1	110.7	115
CSU	193.8	199.7	205.5	211.3	217.1	222.9	228.7	234.5	240.3	246
CNT	720.6	709.7	744.3	786.3	825.6	868.4	903	941.3	980.1	1017.6
INT	299	317.3	353.1	374.9	387.4	397.6	400.9	408.2	403.1	400.2

* A list of the variables used in this and subsequent tables is provided in the appendix II.

nickel can not be sold unless nickel prices fall substantially. However, it is highly unlikely that at such reduced prices current land-based producers of nickel can operate profitably¹.

Almost all the forecasts of the future consumption of Western countries show the same pattern. That is, consumption in all of them fall in 1980 and 1981 and then gradually recover to about their 1979 level in 1983/84. The most significant increase in production of nickel is due to Australian and New Caledonian output of nickel. East-block nations remain more or less self sufficient. Among the nickel consumption by end-uses the stainless steel category has the biggest increase. Nickel prices in general will be rising in nominal terms to 616 cents per pound of nickel in 1989. However, in real terms they will gradually fall in the early 1980's and not recover until 1984. For a complete list of forecasts see Table (13).

2. Forecasts of the Endogenous Variables with the Start of US Stockpile Program in 1985

The current target for the US stockpile is 180 000 metric tons of nickel and some 30 000 tons are being held at the present time. Given the excess supply situation and the large stocks of nickel in the world it is unlikely that any significant government stockpiling will be made in the near future². However, it is useful to investigate the impact of such a program on the world nickel industry even if it is an unlikely event. The 150 000 tons of nickel which are needed to reach the target level of stocks were assumed to spread over four years from 1985 to 1988

¹ The projected price of 434 cents per pound of nickel is only marginally higher than the projected average cost per pound of nickel. For more detail see R. Dick, (November 1981).

² INCO's stocks of nickel alone was estimated to be around 74 000 metric tons of nickel. For more detail see The Financial Times, (25 July, 1981).

with the following distribution:

Year	Tons of Nickel (Addition to Stocks)
1985	30 000
1986	40 000
1987	40 000
1988	40 000

The forecast values of the endogenous variables are reported in Table (14). As expected, nickel prices will be higher than in the previous case where no stockpiling was taking place. World production of nickel during 1985 - 88 goes up almost by the same amount while world consumption of nickel decreases marginally, due to higher nickel prices. The weakening position of Canada is once again confirmed, though Canadian production of nickel will be higher than without the US stockpile program. As a result of higher nickel prices US consumption of nickel in cast iron and non-ferrous alloys shows the largest decline. This is also to be expected since these end-uses have relatively higher price elasticities. World consumption of nickel in 1988 is about 20 000 metric tons less than the previous forecast, obviously due to the higher price of nickel.

3. The Impact of Ocean Mining

One of the main stated policies of the regime to govern ocean mining has been that the activities should be carried out so as to assure

"The protection of developing countries from adverse efforts on their economies or their export earnings from a reduction in the price of an affected mineral, or in the volume of that mineral exported, to the extent that such reductions are caused by activities in the area"¹.

1

Art. 150 (g), Draft Convention on the Law of the Sea, UN DOC/ Revision 2, A/CONF. 62/L. 78, (28. August 1981).

Table (14) - Forecasts of the Future Price, Consumption and Output of Nickel with the Start of the US Stockpile Program in 1985*

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
P	341.1	348.8	358.9	378.8	405.5	445.3	491	530.3	590	630
P/PM	1.19	1.15	1.12	1.11	1.12	1.15	1.21	1.23	1.28	1.28
QNC	197.7	187.4	181.5	181.4	185.6	199	211.6	212.2	216.9	210
AMR	32.7	32.9	41.3	43.8	45	46.1	48.4	48.6	49.5	48.9
OCNR	159.2	156.3	157.2	169.9	183.2	197.6	219.2	235.6	253.4	264.4
ASIR	68.5	72	74.9	78.4	82.6	87.3	93	98	103.5	107.4
AFR	65.1	68.3	70.9	73.7	76.9	80.3	84.1	87.4	90.7	93.3
EUOR	25.7	28.2	30.1	31.75	33.3	35	37	38.8	40.9	42.5
EBTR	189.9	200	210	219.6	229	238.2	247.2	255.9	264.4	272.2
QNW	739	745.5	766.1	798.7	835.8	883.8	940.7	976.8	10.19	10.39
CUSSS	51	49.9	54	58.4	62.5	66.5	68.7	71.5	74.9	79.4
CUSALS	16	17.9	19.5	21.2	22	22.3	22	21.53	21.2	21.4
CUSCI	2.23	1.86	2.36	2.76	2.98	3.2	3.3	3.54	3.82	4.26
CUSNF	50.2	39.3	45.3	50.1	52.4	53.7	53.9	54.8	56.5	60.2
CUSEL	23.4	22.5	22.5	22.3	22.5	23.4	24.2	25	25.6	26.5
CUSCMO	10.1	7.22	7.13	7.13	7.31	7.6	8	8.5	9.1	9.7
CUST	153.1	138.9	150.9	162	169.7	176.9	180.4	185	191.3	201.6
CJA	113.5	114.5	118.8	129	141.1	153	157.5	165.1	173	184
CUK	35	32.7	35.8	39	40.8	43.2	44.6	46.7	48.7	50.5
CGE	68.6	66.7	68.3	73.6	78.1	81.5	85.1	88.3	91.7	95.7
CSW	19.4	20	20.6	21.6	22.5	23.8	25.1	26.3	27.9	28.9
CIT	24.9	24.7	26.3	27.3	28.5	29.7	31	32	33.7	35.1
CFR	38.5	38	37.8	36.2	36.1	37.9	40.4	42.5	44.5	45.5
CMAJ	453.2	435.8	458.7	488.9	517.2	546.2	564.3	586.1	611.2	641.6
CRW	73.6	74.2	80	86	91.2	96	99.4	103.3	107.4	112.5
CSU	193.8	199.7	205.5	211.3	217.1	222.9	228.7	234.5	240.3	246
CNT	720.6	709.7	744.3	786.3	825	865.2	892.5	923.9	958.9	1000.2
INT	299	317.3	353.1	374.9	387.4	397.6	386.3	394.4	407.3	427.9

* See Table (13).

The purpose of this section is to investigate the potential impact of seabed mining on the future production and price of nickel¹.

However, to simulate the present model we must also specify the magnitude of the nickel output from seabed mining. So far, no unique formula has been agreed upon, but a few production formulas have been proposed. The present model was simulated assuming that, on an annual basis,

- (1) 185 000 metric tons of nickel will be recovered under free access to seabed mining,
and
- (2) 100 000 metric tons of nickel will be recovered if access to seabed mining is restricted by a quota system as envisioned by the Draft Convention of the UN Law of the Sea Conference².

The first one allows each of the five big consortias currently involved in ocean mining developments, to operate one mining unit with the capacity to recover 3 million tons of nodules. It is estimated that each mining unit will produce about 35 000 tons of nickel, 30 000 tons of copper, 5 000 tons of cobalt, and 630 000 tons of manganese.

The forecasts of the endogenous variables under each of the above mentioned production quotas are presented in Table (15). The start of seabed mining was assumed to be 1988³. Furthermore, if seabed output comes on stream it is likely that the price of other metals, cobalt in particular, which are also recovered,

¹ Such estimates can form the basis for analysing the potential reduction in the producer countries' export earnings.

² This production figure was chosen as the minimum production quota.

³ This year was chosen for conveniency. Seabed mining is actually expected to begin toward the end of the 1990's or even later, at least not until the property rights issue is satisfactorily settled. We hypothetically chose the year 1988 because forecasts of the nickel market reaching beyond the 1980's seemed very risky. None the less, it should be pointed out that our results qualitatively anticipate the market's behaviour in later years.

will be reduced. Hence, it was assumed that the cobalt price will fall from 12.5 dollars per pound in 1982 to about 6 dollars per pound in 1988.

The forecast values of the endogenous variables are the same from 1980 to 1987, because seabed mining is not assumed for these years. If 100 thousand metric tons of nickel are recovered, the nickel price will fall from 554 cents per pound to 488.8 cents per pound; alternatively, if 185 thousand metric tons of nickel are produced, then the price will fall to 436.5 cents per pound. Almost half of the decrease in the output of the land-based producers is born by Canadian firms (i. e. the price setters), Australia and New Caledonia. The world consumption of nickel increases as a result of the reduced price of nickel, but since the demand for nickel is inelastic, the increase in consumption is small compared to the nickel output from the seabed. Therefore, land-based producers of nickel must cut back and the price must fall.

The country distribution of the reduction in the nickel output of the land-based producers will be a matter of cost efficiency. At the present time, Canadian producers which are endowed with sulfide ores are in an advantageous position, because processing of sulfide ores is less energy intensive than processing of laterite ores. Therefore, any significant reduction in the price of nickel should first have an impact on other, non-Canadian producers of nickel who are endowed with laterite ores¹.

¹ However, the operating costs of the Canadian mines are increasing rapidly. For example, for the settlement of a recent strike at INCO mines in Manitoba the company offered wage increases of 13 % per year for the next three years, and it was rejected by the workers. Much also depends on future costs of energy. If the costs of energy go up in the future as rapidly as they have in the last decade, nickel prices and production of Canada will be significantly higher than the ones shown in Table (15). The closure of Guatemala's nickel laterite mines and the recent developments of Canadian mines are indicative of the way Canadian producers see future energy costs.

Table (15) - Forecasts of the Future Price, Consumption and Output of Nickel with the Start of Seabed Mining in 1988*

	With 100,000 Tons of Nickel Recovered		With 185,000 Tons of Nickel Recovered	
	1988 -	1989	1988	1989
P	488.8	566.8	436.5	482.1
P/PM	1.06	1.13	.95	.964
QNC	162	184	132	147
AMR	45.1	45.3	42.8	40.1
OCNR	219.5	223.7	207.7	192
ASIR	96	96.5	91.9	88.9
AFR	88	90	86.9	87.6
EUOR	38.5	39.3	37.6	37.2
EBTR	264.4	272.2	264.4	272.2
QNW	913	952	863	865
CUSSS	81.4	87	83.9	93.2
CUSALS	26.1	27.6	26.8	30.1
CUSCI	4.9	5.54	5.3	6.4
CUSNF	69.7	75.5	74.7	88.1
CUSEL	26.7	28.3	26.9	29
CUSCMO	9.6	10.49	9.7	10.8
CUST	218.6	234.6	227.6	257.9
CJA	173.2	184.3	173.2	184.4
CUK	51	53.6	51.7	55.4
CGE	94.4	98.8	95.4	101.4
CSW	27.9	28.9	27.9	28.9
CIT	33.7	35.1	33.7	35.1
CFR	45.6	47.8	45.6	48.3
CMAJ	644.7	683.4	655.3	711.6
CFW	111.9	113.2	112.5	116.2
CSU	238.9	239.8	237	236.9
CNT	995.5	1036.5	1005	1064
INT	403	421.5	403	445.8

* See Table (13).

V. Summary and Conclusions

This study provides a brief, yet general, summary of the main characteristics of the world nickel industry. In chapter II the main features of the supply and demand sides of the nickel market were discussed. It was demonstrated that the geographical patterns of production and consumption of nickel have changed considerably. Namely, on the production side the share of the Canadian producers has been drastically reduced from about 85 % of the world output in 1940's to about 25 % in 1980. However, other producers such as Australia, the Soviet Union and New Caledonia have increased their market shares. The geographical pattern of consumption has undergone a similar change. The United States accounted for about two-thirds of the world consumption of nickel in the 1940's, but at the present time consumes less than 25 % of the world output of nickel. Other countries, Japan and the Soviet Union in particular, have significantly increased their shares in the world consumption of nickel. Developing nations account for a small percentage of the total consumption of nickel but nickel consumption in some of these countries, India and Brazil, is expanding rapidly.

Future consumption and production of nickel, however, will be expanding at a much slower pace than in the past three decades. The reasons for this reduction in rates of growth can be summarized as (a) the current slowdowns in the industrialized nations economic activities, (b) the high rates of interest currently prevailing in these countries which result in a lower demand for metal (nickel) intensive capital equipments, (c) the change in the pattern of demand away from metal intensive goods and towards services and goods with high value added and low metal content such as computers and electronics, and (d) the reduced output of the military hardwares

in the 1970's. Since none of these factors, except maybe the last one, is expected to change significantly in the near future; we believe that future consumption of nickel will be growing at about 3 % per year.

The availability of nickel, therefore, is not a matter of concern in the next two decades because (1) there is a huge stock of nickel available at the present time, (2) the nickel producers are operating at 70 % of capacity, and (3) many new capacities have been recently installed. Furthermore, given the almost unlimited amounts of nickel which can be recovered from the ocean floor, it is highly unlikely that any serious shortages can develop unless, of course, there is a long strike at one of the major producers of nickel.

Price stability and market disequilibrium have been the salient features of the nickel industry. It is generally acknowledged that the International Nickel Company of Canada (INCO) often acts as a price leader. The price is usually set, and production plans are made, according to the current and expected future market conditions. However, when such expectations are proved to be wrong the price is usually maintained rather than letting it respond to the market situation. This amounts to the industry experiencing periods of shortage and overproduction. Clearly such imbalances, along with other factors, ought to influence the price and production plans of the next period.

This, we believe is an important aspect of the nickel market which has received little attention in the past. The hypothesis put forward in this study is that it does not really matter whether nickel stocks are high or low; what is of importance is by how much current stocks exceed or fall short of their desired levels. INCO's price setting and production decisions were derived in the light of the above argument. Our

empirical results in chapter III confirmed our hypothesis. The estimated demand equations for different countries and different end-uses were also presented in the same chapter together with the supply equations for the world producers of nickel. The estimated price elasticity of the non-communist countries' demand for nickel was found to be inelastic in the short-run and of unit elasticity in the long-run. This was expected since although other metals can be used as substitutes for nickel, they are often either more expensive or such substitutions imply a sacrifice in the quality of the product. The estimated price elasticity of the supply of nickel is close to one in the short-run and is significantly greater than one in the long-run. This, too, was expected since there are ample nickel resources in the world which, compared with Canadian sulfide ores, have lower nickel content. However, the technological breakthrough in the 1960's and the rising price of nickel in the 1960's and 1970's have made the recovery of nickel from low-grade ores profitable, yet recent increases in energy costs have significantly reduced the profitability of some of these projects.

The recovery of nickel from the ocean floor cannot be expected to begin sooner than in the late 1980's. Since the start of seabed mining is certain to increase the supply of nickel, and hence reduce the price, a majority of states represented at the Third United Nations Conference on the Law of the Sea have expressed their concerns about the impact of the recovery of manganese nodules on the markets of the related metals. They argue that the reduced price and production of the current land-based producers of nickel will significantly diminish the export earnings of the producer countries. Therefore, they are insisting on, among other things, (1) production controls on seabed mining, and (2) compensation of current land-based producers

for a potential loss of revenues. Therefore, it was thought to be of some interest to simulate the present model under alternative scenarios proposed so far, and likely in the future, and quantify the magnitude of the change in price and output of nickel from land-based sources.

First, the model was simulated on the assumption that no seabed mining will start in 1988. The forecasts of the endogenous variables contained some interesting information. To begin with, world nickel consumption in 1985 will be lower than the estimates discussed in the United Nations Conference. The rapid rise in the price of nickel in 1979 - 1980 and the world recession in 1980 - 1981 account for the lower forecasts given in this study. Nickel prices will rise in nominal terms up to 1989, but in real terms they will slightly fall before recovering in 1984. Production of nickel follows a similar pattern.

Next, the model was simulated assuming that (a) the US government will start a stockpiling program in 1985, (b) one hundred thousand metric tons of nickel will be recovered from the ocean in 1988, and (c) one hundred and eighty five thousand tons of nickel will be extracted from the seabed. The results are intuitively plausible. Production and prices are higher and consumption figures are lower with the US stockpiling than in the previous case. The start of seabed mining, on the other hand, has the opposite effect. That is, production of nickel from land-based sources as well as the price of nickel fall significantly, while world consumption of nickel is higher than in the previous simulations. Since the fall in price of nickel is substantial

it is likely that the less important land-based producers who are recovering nickel from laterite ore will be affected before Canadian producers, though operating costs of Canadian nickel mines are rising rather sharply. Anyhow, the big nickel producer countries in the West, Canada and Australia, will have to bear the greatest burden from the reduction in prices and output.

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Appendix I

Estimating World Stocks of Nickel

Since production data show the amount of nickel mined in different countries at different stages of production, it was necessary to adjust these data when totalling world production. The following formula was used to calculate changes in the world stocks of nickel.

$$\Delta INT = (QNC + NCL + SAF + USA + DPR + BUR + GRE + YOG) + .86^* (EBT) + .975^* (FIN + NOR + AUS + ZIM) + .858^* (BOT) + .9^* (BRA + GUA + MOR + PHI + IND) - CNT - Z$$

where

ΔINT = estimated change in the world's stocks of nickel

QNC = nickel production of Canada

NCL = nickel production of New Caledonia

SAF = nickel production of South Africa

USA = nickel production of United States

DPR = nickel production of Dominican Republic

BUR = nickel production of Burma

GRE = nickel production of Greece

YOG = nickel production of Yugoslavia

EBT = nickel production of East-block countries

FIN = nickel production of Finland

NOR = nickel production of Norway

AUS = nickel production of Australia

ZIM = nickel production of Zimbabwe

BOT = nickel production of Botswana

BRA = nickel production of Brazil

GUA = nickel production of Guatemala

MOR = nickel production of Morocco

PHI = nickel production of Philippine

IND = nickel production of Indonesia

CNT = world consumption of nickel

Z = change in the U.S. strategic stockpile of nickel

The above mentioned weights were derived by considering the amount of nickel which will be lost in concentrating and smelting different sulfide and laterite ores. The world stocks of nickel were estimated by adding the above mentioned changes to the world stocks of nickel in 1954, which are estimated to have been about 29 thousand metric tons of nickel¹.

¹ Charles River Associates, (1976).

Appendix II

List of Variables and Data Sources

<u>Symbol</u>	<u>Units</u>	<u>Title</u>	<u>Source</u>
P	Cents per Pound	Producer Price of Nickel	Metal Statistics
P _M	1967 = 100	US Producer Price for Metals and Metal Products	Survey of Current Business
R	Percent	3-Month US Government Security Yields	Survey of Current Business
CNT	1000 Metric Tons	World Consumption of Nickel	Metal Statistics
INT	" " "	World Stocks of Nickel	Construct
ΔINT	" " "	Change in the World Stocks of Nickel	Construct
QNC	" " "	Canadian Production of Nickel	Metal Statistics
EBT	" " "	Soviet-Block Mine Output of Nickel	Metal Statistic
EBTR	" " "	Soviet-Block Output of Refined Nickel	Construct
AM	" " "	Nickel Mine Output of Other American Nations	Metal Statistics
AMR	" " "	Nickel Recovered from the Mine Output of other American Nations	Construct
AF	" " "	Nickel Mine Output of African Nations	Metal Statistics
AFR	" " "	Nickel Content of the Mine Output of African Nations	Construct
EUO	" " "	Nickel Mine Output of Western European Nations	Metal Statistics

<u>Symbol</u>	<u>Units</u>	<u>Title</u>	<u>Source</u>
EUOR	1000 Metric Tons	Nickel Content of Europe Mine Production	Construct
AUS	" " "	Mine Output of Australia	Metal Statistics
NCL	" " "	Recovered Nickel Output of New Caledonia	Minerals Yearbook
OCNR	" " "	Recovered Nickel Output of Australia and New Caledonia	Construct
ASI	" " "	Nickel Mine Output of Asia	Metal Statistics
ASIR	" " "	Recovered Nickel Output of Asian Nations	Construct
CUST	" " "	US Consumption of Nickel	Minerals Yearbook
CUSSS	" " "	US Consumption of Nickel in Stainless Steels	Minerals Yearbook
CUSALS	" " "	US Consumption of Nickel in Alloy Steels	Minerals Yearbook
CUSCI	" " "	US Consumption of Nickel in Cast Iron	Minerals Yearbook
CUSEL	" " "	US Consumption of Nickel in Electroplating	Minerals Yearbook
CUSNF	" " "	US Consumption of Nickel in Super Alloys and other Non-Ferrous Alloys	Minerals Yearbook
CUSCMO	" " "	US Consumption of Nickel in Chemical, Magnets and other Uses	Minerals Yearbook
CJA	" " "	Nickel Consumption of Japan	Metal Statistics
CUK	" " "	Nickel Consumption of UK	Metal Statistics
CGE	" " "	Nickel Consumption of Germany	Metal Statistics

<u>Symbol</u>	<u>Units</u>	<u>Title</u>	<u>Source</u>
CFR	1000 Metric Tons	Nickel Consumption of France	Metal Statistics
CIT	" " "	Nickel Consumption of Italy	Metal Statistics
CSW	" " "	Nickel Consumption of Sweden	Metal Statistics
CSU	" " "	Nickel Consumption of East-Block Nations	Metal Statistics
CNT	" " "	World Consumption of Nickel	Metal Statistics
CRW	" " "	Nickel Consumption of other Western Nations	Construct
CMAJ	" " "	Nickel Consumption of Major Nickel Consumers	Construct
SSUS	" Short "	US Production of Stainless Steels	Metal Bulletin
SSJA	" " "	Japanese Production of Stainless Steels	Metal Bulletin
SSUK	" " "	UK Production of Stainless Steels	Metal Bulletin
SSGE	" " "	German Production of Stainless Steels	Metal Bulletin
SSFR	" " "	French Production of Stainless Steels	Metal Bulletin
SSIT	" " "	Italian Production of Stainless Steels	Metal Bulletin
SSSW	" " "	Swedish Production of Stainless Steels	Metal Bulletin
YDMAN	1967 = 100	US Index of Production of Durable Manufactures	Federal Reserve Bulletin
CDMAN	1967 = 100	US Index of Consumer Durables	Federal Reserve Bulletin

<u>Symbol</u>	<u>Units</u>	<u>Title</u>	<u>Source</u>
YPEQ	§ Billion	US Plant and Equipment Expenditure	Federal Reserve Bulletin
YJA	1975 = 100	Japanese Industrial Production	International Financial Statistics
YUK	1975 = 100	UK Industrial Production	International Financial Statistics
YGE	1975 = 100	German Industrial Production	International Financial Statistics
YFR	1975 = 100	French Industrial Production	International Financial Statistics
YIT	1975 = 100	Italian Industrial Production	International Financial Statistics
USALS	1000 Short Tons	US Production of Alloy Steels	Metal Statistics
YELM	1967 = 100	US Production of Electical Machinery	Federal Reserve Bulletin
YW	1975 = 100	OECD Industrial Production	OECD Financial Statistics
Z	1000 Metric Tons	Change in US Government Stockpile of Nickel	Hilmy, World Bank
PS	§ / Net Ton	Cold Finished Steel Bar Price	Metal Statistics
CCP	1975 = 100	Canadian Consumer Price Index	International Financial Statistics

<u>Symbol</u>	<u>Units</u>	<u>Title</u>	<u>Source</u>
EXC	¢ Canadian/ US Dollar	US - Canadian Dollar Exchange Rate	International Finan- cial Statistics
WPUS	1975 = 100	US Wholesale Price Index	International Finan- cial Statistics
WPUK	1975 = 100	UK Wholesale Price Index	International Finan- cial Statistics
WPGE	1975 = 100	German Wholesale Price Index	International Finan- cial Statistics
WPFR	1975 = 100	French Wholesale Price Index	International Finan- cial Statistics
WPJA	1975 = 100	Japanese Wholesale Price Index	International Finan- cial Statistics
EXJA	Yen/US Dollar	US Dollar Exchange Rate with Japanese Yen	International Finan- cial Statistics
EXFR	Franc/US Dollar	US Dollar Exchange Rate with French Franc	International Finan- cial Statistics
EXUK	Cents/Pound	US Dollar Exchange Rate with British Pound	International Finan- cial Statistics
EXGE	DM/US Dollar	US Dollar Exchange Rate with Deutsche Mark	International Finan- cial Statistics

<u>Symbol</u>	<u>Units</u>	<u>Title</u>	<u>Source</u>
D2	1972-79 = 1 ^a	Dummy Variable for the Start of Dominican Republic Nickel Operation	-
D6	1958-61 = 1 ^a	Dummy Variable for Cuban Reproduction	-
D7	1977-79 = 1 ^a	Dummy Variable for the Start of Indonesian Nickel Operation	-
D62, D71	1962, 1971 = 1 ^a	Dummy Variable for Closure of SLN in 1962 and 1971	-
D67, D68, D69	1967, 1968, 1969 = 1 ^a	Dummy Variable for Nickel Shortage	-
D69, D75, D78, D79	1969, 1975, 1978, 1979 = 1 ^a	Dummy Variable for Strikes in Canadian Nickel Industry	-
D77	1977 = 1 ^a	Dummy Variable for Strikes in Greece Nickel Industry	-
MAV (X,i)	-	Moving Average of the Variable X Using i Lags	-
WAV (X,i)	-	Weighted Average of the Variable X Using i lags	-
T	1956 = 1 ^b	Time	-
TD	1971 = 1 ^b	Dummy Variable Used to Capture the Reduced Nickel Intensity in the 1970's	-
t	¢/lb	US Nickel Tariff	Metal Statistics
D57, D58	1957, 1958 = 1 ^a	Dummy Variable for the Change in Demand for Nickel by Electroplaters	-
D79 OIL	1979 = 1 ^a	Dummy Variable for the Increase in the Price of Oil	-
ΔINT*	1000 Metric Tons	Desired Change in the World's Stocks of Nickel	Construct

^a Equal to zero in other years.

^b Increases linearly, thereafter.

<u>Symbol</u>	<u>Units</u>	<u>Title</u>	<u>Source</u>
QPLA	Troy Ounces	South African Production of Platinum Group Metals	Minerals Yearbook
PCO	\$ / lb	US Price of Cobalt	Metal Statistics
PCU	¢ / lb	US Price of Copper	Metal Statistics
PCH	\$ / Metric Tons	US Price of Chromite	Metal Statistics
PAL	¢ / lb	US Price of Aluminium	Metal Statistics
PMAN	\$ / Gross Ton	US Price of Manganese	Metal Statistics
PCAD	¢ / lb	US Price of Cadmium	Metal Statistics
PMOL	¢ / lb	US Price of Molybdenum	Metal Statistics

Appendix III

Exogenous Variables Forecasts

	<u>t</u>	<u>D58</u>	<u>D57</u>	<u>D6</u>	<u>D66</u>	<u>D67</u>
1980	0	0	0	-1	0	0
1981	0	0	0	-1	0	0
1982	0	0	0	-1	0	0
1983	0	0	0	-1	0	0
1984	0	0	0	-1	0	0
1985	0	0	0	-1	0	0
1986	0	0	0	-1	0	0
1987	0	0	0	-1	0	0
1988	0	0	0	-1	0	0
1989	0	0	0	-1	0	0

	<u>D69</u>	<u>D75</u>	<u>D78</u>	<u>D79</u>	<u>TD</u>	<u>D62</u>
1980	0	0	0	0	9.5	2
1981	0	0	0	0	10	1
1982	0	-0.2	0	0	10.4	0.5
1983	0	-0.4	0	0	10.8	0
1984	0	-0.6	0	0	11.1	0
1985	0	-0.8	0	0	11.4	0
1986	0	-1	0	0	11.6	0
1987	0	-1	0	0	11.8	0
1988	0	-1	0	0	11.9	0
1989	0	-1	0	0	12	0

	<u>PAL</u>	<u>PCU</u>	<u>YDMAN</u>	<u>CDMAN</u>	<u>YELM</u>
1980	69.5	102	136.6	136.5	172.7
1981	76	87	143	143	178
1982	83	98	150	150	186
1983	90	104	157	157	195
1984	98	112	165	165	205
1985	106	118	175	174	216
1986	112	125	184	181	226
1987	118	132	194	188	236
1988	124	140	204	195	247
1989	132	149	214	204	259

	<u>SSGE</u>	<u>SSIT</u>	<u>SSJA</u>	<u>YPEQ</u>	<u>PMOL</u>
1980	800	480	1900	194	820
1981	830	490	1950	214	830
1982	870	530	2050	238	840
1983	920	560	2250	268	860
1984	970	590	2475	298	880
1985	1000	620	2700	335	900
1986	1040	650	2800	370	930
1987	1080	680	2950	407	960
1988	1120	710	3100	445	990
1989	1170	740	3300	490	1040

	<u>PCH</u>	<u>USALS</u>	<u>PMAN</u>	<u>PCO</u>	<u>PCAD</u>
1980	56	18500	510	25	280
1981	61	18000	510	14	240
1982	65	18400	520	11.5	255
1983	70	18700	535	11	275
1984	75	19000	550	11.5	295
1985	80	19400	575	12	320
1986	85	19800	595	12.5	345
1987	90	20200	620	13.5	370
1988	95	20700	660	14.5	390
1989	100	21200	680	15.5	410

	<u>D2</u>	<u>D7</u>	<u>D77</u>	<u>SSSW</u>	<u>D79OIL</u>
1980	0.5	1	0	350	1
1981	1	1	0	360	.90
1982	1	1	0	370	.81
1983	1	1	0	385	.80
1984	1	1	0	400	.80
1985	1	1	0	420	.80
1986	1	1	0	440	.80
1987	1	1	0	460	.80
1988	1	1	0	485	.80
1989	1	1	0	500	.80

	<u>Y</u>	<u>Z</u>	<u>R</u>	<u>CCP</u>	<u>D68</u>
1980	123	0	11.5	154	0
1981	124	0	14.6	173	0
1982	127	0	14.5	190	0
1983	131	0	13.5	205	0
1984	136	0	12.5	219	0
1985	141	0	11.5	236	0
1986	147.5	0	11	251	0
1987	155	0	10.5	268	0
1988	163	0	10	290	0
1989	171	0	10	314	0

	<u>EXC</u>	<u>PS</u>	<u>T</u>	<u>QPLA</u>	<u>WPUS</u>
1980	.85	27.5	25	3350	153.6
1981	.83	29.1	26	3500	168
1982	.83	31	27	3650	178
1983	.83	33	28	3800	188
1984	.83	35	29	3950	200
1985	.83	37.2	30	4100	214
1986	.83	39.5	31	4200	225
1987	.83	42.7	32	4300	236
1988	.83	46.1	33	4400	247
1989	.83	49.7	34	4500	260

	<u>PM</u>	<u>EXUK</u>	<u>EXJA</u>	<u>WPUK</u>	<u>WPJA</u>
1980	286	232	.4774	200	200
1981	301	210	.46	222	206
1982	320	180	.48	240	212
1983	340	180	.495	260	218
1984	360	180	.51	280	222
1985	385	180	.52	300	226
1986	405	175	.54	320	232
1987	430	175	.58	342	238
1988	460	175	.62	364	245
1989	500	175	.64	384	255

	<u>EXFR</u>	<u>EXGE</u>	<u>WPFR</u>	<u>WPGE</u>	<u>D71</u>
1980	23.69	1.8177	145.8	121.5	0
1981	18	2.27	163	129.5	0
1982	16	2.15	181	134.5	0
1983	16	2.05	200	140	0
1984	16	2	218	146	0
1985	16	1.90	238	152	0
1986	15.5	1.85	255	158	0
1987	15.5	1.85	274	165	0
1988	15	1.80	290	172	0
1989	15	1.80	310	178	0

	<u>YUK</u>	<u>YGE</u>	<u>YFR</u>	<u>YIT</u>	<u>YJA</u>
1980	105.1	118	116	130.4	142.5
1981	100	118	114	128	146
1982	102	120	117	131	150
1983	106	125	121	134	156
1984	110	130	125	139	162
1985	115	136	131	145	170
1986	119	142	137	150	178
1987	123	148	143	156	186
1988	128	155	149	162	195
1989	133	162	155	168	204

	<u>SSUS</u>	<u>SSUK</u>	<u>SSFR</u>	<u>RESI</u>
1980	2150	210	630	0
1981	2200	200	630	0
1982	2260	205	660	0
1983	2350	213	690	0
1984	2470	222	730	0
1985	2590	231	770	0
1986	2700	240	800	0
1987	2800	250	830	0
1988	2900	262	870	0
1989	3000	275	900	0