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Political Risk and The Trend of New Investment in the World Aluminum Industry

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The world aluminum industry will require significant expansion of capacity in mining, refining, and smelting by the year 2000. The World Bank has presented a cost model with the single objective of cost minimization. Concluding that the majority of new investment can be expected to occur in lesser developed countries. This study utilizes compromise programming to evaluate the impact of political risk as well as cost minimization. Consideration of risk modifies the World Bank forecast, resulting in increased expected investment in industrialized countries as risk consideration increased. This result compares favorably with actual investment trends observed.

I. Introduction

Forecasting economic developments is an increasingly important function for all market participants. This is particularly true for the investment trend and climate in the primary aluminum industry which is of concern to at least three groups of agents: First, the industrialized countries' governments due to the strategic nature of the metal; second, the multinational corporations

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(MNCs) concerned about factors such as profitability and risk of investment and market shares; third, a group of developing countries which rely upon bauxite deposit mining as a crucial contribution to domestic economic activity and as a source of foreign exchange. Thus, modeling the aluminum industry to provide a plausible prediction of investment trends is a relevant exercise.

The world primary aluminum industry[1] is characterized by the need for expansion in productive facilities by the year 2000 (Figure 1). The World Bank/OECD (Organization for Economic Cooperation and Development) has studied this market with a focus upon expected investment patterns (Brown, et al.). That model, in the form of a 0-1 linear programming model, captured the technological and cost elements of the market. The World Bank/OECD conducted the study on the basis of cost minimization, with extensive parametric analyses to reflect changes in electrical, operating, and capital costs; trade blockages; and levy and tariff policies. That study concluded that new investment would occur primarily in lesser developed countries (LDCs).[2] However, it is also a widely recognized fact that there has been a decline in the share of total equity investment in developing countries by international mining companies (Mikesell; Loewinger; Radetzki and Zorn). This trend has been attributed to the wave of nationalizations of foreign owned mines in the 1960's and early 1970's, the growth of state-owned mining enterprise, and the increasingly frequent requirement of oral participation in foreign mining projects.

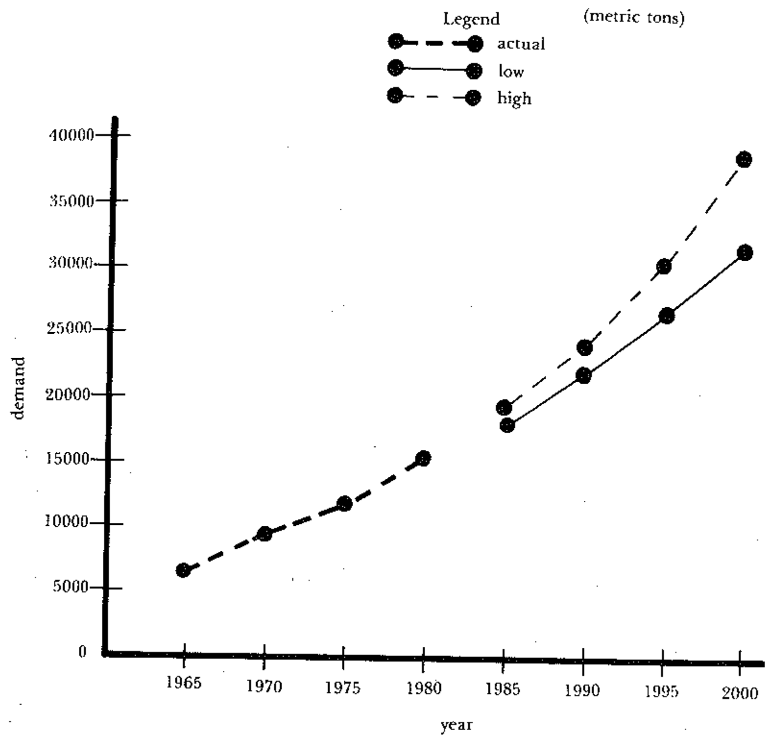
The World Bank/OECD report noted that their study did not directly consider the elusively measurable factors of risk. While the model included differential factors for cost of capital based upon infrastructure development, it did not directly consider political risk to the multinational corporations (MNCs). This study seeks to model political risk measures in order to supple-

1 "Primary aluminum industry" refers to the mining, refining and smelting of aluminum. These three distinctive stages of aluminum production may or may not take place in the same location.

2 The study predicted that "more than 90 percent of all new bauxite mine capacity would be installed in LDC's. In the case of alumina, 85 percent of new capacity would be installed in LDC's......Almost three-quarters of all capacity for aluminum smelting would in fact be installed in LDC's" (Brown, et al., p. 62).

Figure 1

ALUMINUM DEMAND



Sources: Nonferrous Metal Date (annual)

Brown, et al. (1983), tables 3 and 4

ment the World Bank model. The technique used is compromise programming (Zeleny; Gearhart; Ecker and Shoemaker). This technique allows consideration of nondominated solutions which reflect various weightings of the alternative objective functions of cost minimization and risk minimization. While the result yields no predictive outcome, it does allow a measure of the tradeoff in outcomes between these conflicting objectives. This approach also reduces the difficulties in measuring political risk and cost on a common scale. While political risk is difficult to measure in terms of cost, it is more easily measured in an ordinal way.

This paper examines the worldwide primary aluminum industry and the cost models considered (section II), the measures of political risk used (section III), and the compromise programming technique used with the network model (section IV). Section V presents findings compared with the World Bank model. Section VI presents conclusions.

II. World Aluminum Model

The primary aluminum industry is a series of three production processes. Bauxite is mined at a limited number of economically feasible sites. The ores mined vary a great deal in aluminum content, requiring significantly greater quantities of ore to be processed in some locations relative to others. This bauxite ore is refined into alumina. Refineries use one of four processes, depending upon the type of ore being refined. Because of the differences in ore and refining processes, not all refineries can process all bauxites. There are significant cost differentials in these four refining technologies. The last process smelts refined alumina into primary aluminum. Smelting shrinks 1.93 ton of alumina into one ton of aluminum. Smelting is an intensive user of electricity. The market for these products is primarily aluminum, although alternative uses for bauxite and alumina also exist. Good references for the current aluminum industry are Woods, et al. and Stuckey.

The primary outcome of interest in this study is the comparison of the relative share of new investment expected in LDCs. The alternative sites for future investment are more industrialized countries (OECD). In addition, two relatively isolated economies (East Europe/USSR and China) have aluminum facilities as well. While China is a developing country, and is treated as such in the World Bank model, the opportunity for investment by multinational aluminum companies is limited. Therefore, this study treats East Europe/USSR and China as a separate sector. Both the World Bank study and this study block trade between East Eruope/USSR and China to reflect current realities. Table 1 gives countries included by sector.

A. World Bank Model

The World Bank model of this industry is a 0-1 linear pro-

Table 1

ALUMINUM INDUSTRY COUNTRIES BY SECTOR

LDC	Jamaica, Haiti/Domnican, Guyana, Surinam, Brazil, Venezuela, Ghana, Guinea, Sierra Leone, Cameroun, India Indonesia, Malaysia, Turkey, Mexico, Argentina, Egypt, Zaire, South Africa, ASEAN, Korea/Taiwan, Mideast
OECD	USA, West Europe, Australia, Canada, Japan
Other	East Europe, USSR, China

Source: Brown, et al.

gramming model. While production efficiencies do exist, the large impact of transportation, the limited capacities present in ore reserve capacities and smelting electricity, and the capital intensive nature of refining operations make the 0-1 model appropriate for the purpose of the model, which is to identify likely locations for increases in productive capacity. Because the purpose is to identify expected changes due to demand increases, existing facilities are constrained to at least current capacities. The aluminum industry has traditionally operated near full capacity, resorting to stockpiling rather than reducing operations during demand declines.

The variables of the model are:

For M mines (22 in the model)

X_m is current mine capacity

X_m* is new mine capacity

For R refineries (84 in the model by ore type)

X_r is current refinery capacity

X_r* is new refinery capacity

For S smelters (29 in the model)

X_s is current smelting capacity

X_{sl}* is new low cost electricity smelting

X_{sh}* is new high cost electricity smelting

For D demands (18 in the model)

DEM_d is expected aluminum demand in year 2000 by market

DEM_{bm} is expected nonaluminum demand for bauxite by mine in year 2000

DEM_{ar} is expected nonaluminum demand for alumina by refinery in 2000

For each compatible mine-refinery pair

X_{mr} is the quantity mined at m shipped to refinery r

For each refinery-smelter pair

X_{rs} is the quantity refined at r shipped to smelter s

For each smelter-demand pair

X_{sd} is the quantity smelted at s shipped to market d

Zero-one variables included in the World Bank model:

Y_m is a 0-1 variable for expanding mine m to a capacity limit of 16 million metric ton per year

Y_r is a 0-1 variable for expanding refinery r to a capacity limit of 2 million metric ton per year

Y_s is a 0-1 variable for expanding smelter s with a capacity limit of 200 thousand metric ton (kmt) per year

Shrink coefficients of the model:

σ_m is the shrink factor for bauxite/alumina, varying by mine

σ_r is the shrink factor for alumina/aluminum (1 T aluminum requires 1.93 T alumina)

The objective function minimizing cost:

$$\text{Min } Z_c = \sum_{m=1}^{M} (X_m + X_m^*)C_m + \sum_{m=1}^{M} \sum_{r=1}^{R} X_{mr}C_{mr} + \sum_{r=1}^{R} (X_r + X_r^*)C_r + \sum_{r=1}^{R} \sum_{s=1}^{S} X_{rs}C_{rs} + \sum_{s=1}^{S} (X_sC_s + X_{sl}^*C_{sl}^* + X_{sh}^*C_{sh}^*) + \sum_{s=1}^{S} \sum_{d=1}^{D} X_{sd}C_{sd} + \sum_{m=1}^{M} Y_mF_m + \sum_{r=1}^{R} Y_rF_r + \sum_{s=1}^{S} Y_sF_s$$

where C_m is the cost of mining 1 metric T at mine m (operating + capital)

C_{mr} is the shipping cost for 1 metric T of bauxite from m to r

C_r is the cost of refining 1 metric T at refinery r (operating + capital)

C_{rs} is the shipping cost for 1 metric T from refinery r to smelter s

C_s is the cost of smelting 1 metric T at existing smelter s

C_{sl}^* is the cost of smelting 1 mT at s using available low cost electricity

C_{sh}^* is the cost of smelting 1 mT at s with high cost electricity

C_{sd} is the shipping cost for 1 mT from s to d

F_m is the fixed cost for expanding mine m up to 16,000 kmt capacity

F_r is the fixed cost for expanding refinery r up to 2,000 kmt capacity

F_s is the fixed cost for expanding smelter s up to 200 kmt capacity

B. Constraints

For each mine m ($m = 1,\ldots,22$)

X_m = current capacity

$X_m^* \leqslant 0.05$ reserve capacity

Balance between mine production and refinery production

$$X_m + X_m^* = DEM_{bm} + \sum_{r=1}^{R} X_{mr}$$

For each refinery r ($r = 1,\ldots,84$)

$$\sum_{m=1}^{M} {}_mX_{mr} = X_r + X_r^*$$

X_r = current capacity

$$X_r + X_r^* = DEM_{ar} + \sum_{s=1}^{S} X_{rs}$$

For each smelter s ($s = 1,\ldots,29$)

$$\sum_{r=1}^{R} {}_rX_{rs} = X_s + X_{s1}^* + X_{sh}^*$$

X_s = current capacity

$X_{s1}^* \leqslant$ available low cost capacity

$$x_s + X_{s1}^* + X_{sh}^* = \sum_{d=1}^{D} X_{sd}$$

For each each demand D ($d = 1,\ldots,18$)

$$\sum_{s=1}^{S} X_{sd} = DEM_d$$

Fixed costs constraints

$$X_m{}^* \leqslant Y_m M' \quad \text{where } M' \text{ is arbitrarily large (for all } m)$$
$$X_r{}^* \leqslant Y_r M' \qquad \text{(for all } r)$$
$$X_{s1}{}^* + X_{sh}{}^* \leqslant Y_s M' \qquad \text{(for all } s)$$

C. Network Model

The structure of the World Bank model is suitable for network flow modeling, being a multistage capacitated system (Zahorik, et al.). The 0-1 features of the World Bank model were not used, due to excessive computational requirements. While a 0-1 algorithm was not used, costs of resulting solutions were calculated including fixed costs developed by the World Bank study. Care was taken to validate results to assure:

1) the data used was accurate relative to the study compared with, and

2) that the 0-1 results were not substantially different.

Table 1 demonstrates that for mines and smelters, relative shares of the two models were very similar. For capital intensive refineries, there were differences, although the continuous network cost minimization model yielded a higher share for LDCs. Detailed differences can be examined in the first two columns of results given in the Appendix.

III. Political Risk

The domestic theory of the firm reveals that real investment decisions are taken for stockholders to earn a risk-free rate of return plus a premium commensurate with the systematic (non-diversifiable) risk of the project. The relevant risk measure is the covariance of the random project returns with the returns of the market portfolio, of which one of several proxies available can be used. There appears to be no reason why the basic concept should not hold for the transnational firm as well. However, the computation of the relevant measure of risk, a purely statistical prob-

Table 2

COMPARISON OF COST MINIMIZATION MODELS: PROPORTIONATE SHARE OF NEW INVESTMENT

	LDC	OECD	East Europe/ China
Mines			
0-1 Model	1.00	0	0
Network Model	.98	0	.02
Refineries			
0-1 Model	.71	.15	.15
Network Model	.94	.06	0
Smelters			
0-1 Model	.69	.22	.09
Network Model	.71	.04	.26

lem for the domestic firm, runs into theoretical and practical difficulties in the international context. This is particularly true for firms operating in developing countries with more or less rudimentary financial markets. Besides, modern international capital asset pricing models (ICAPM) in general assume that risks such as expropriation, currency control and foreign exchange changes, are nonsystematic (and therefore not priced) (Grauer, Litzenberger and Stehle).[3] However, surveys and case studies of multinational corporations have indicated that in addition to profit maximization, political risk does play an important role in capital budgeting decisions (Bhalla; Blank, et al.; Haendel, et al.; Harnes; Kobrin; Loewinger; Radetzki and Zorn). That is, corporations base their investment decision based on the total (systematic and unsystematic) risk of the project rather than on the systematic component. Furthermore, in the assessment of the riskiness of alternative projects in the international context, the

[3] ICAPM also yield that foreign investment may *reduce* the systematic risk by supplying international diversification. This result may hold for a number of possible distributions of investments abroad, and it is possible to conceive a particular distribution of investment locations that optimizes the risk-return tradeoff function of the MNC.

evaluation of political risk plays a substantial role. In the mining industry, the increased use of political risk as a criterion for investment decisions is reflected in the shifting of investments by multinational corporations away from the third world. This shift is occurring despite the fact that in many instances those countries offer obvious advantages from the cost point of view. Blank, et al. indicated that in 80 percent of new investment proposals and in 71 percent of the cases when strategic planning is performed, political risk evaluation is systematically performed.

Political risk involves the possibility of loss due to expropriation, confiscation, contractual disruption and destruction of property. The measurement of political risk can be helped by the use of scientific procedures. This assessment can also be improved by a careful research of the political and social characteristics of the country in question, and an *in-situ* inspection will help to acquire this information. But, ultimately the assessment of the risk situation of a particular project will be, in the end, highly subjective. A number of recent studies tend to indicate that political risk is not uniform for all firms. The data clearly show that companies differ in their susceptibility to political risk, depending on their industry, size, composition of ownership, level of technology, and degree of vertical integration with other affiliates. For example expropriation or creeping expropriation is more likely to occur in the extractive, utility, and financial services sectors of an economy than in a manufacturing sector. Table 3, based on data compiled by Bradley, shows corporate susceptibility to expropriation by industry.

Table 3 reveals that extractive industries, which usually entail large investments to be economically feasible, have suffered the highest incidence of expropriation. Thus, it is reasonable to conclude that these industries will be particularly inclined to evaluate political risk in their investment decisions.

A. Measuring Political Risk

Existing models of political risk assessment fit into two basic categories: those aggregating subjective assessment and those relying on quantified indicators of economic, social and political factors (Kobrin). The former evaluate the investment climate of countries using the Delphi technique of pooling the opinion of a

Table 3

EXPROPRIATION BY INDUSTRY GROUP, 1960-1974

Industry	Number of Expropriations	Percent of Total
Oil	84	12.0
Extraction	38	18.0
Utilities and Transportation	17	4.0
Insurance and Banking	33	4.0
Manufacturing	30	1.2
Agriculture	19	n.a.*
Sales and Services	16	n.a.*
Land, Property and Construction	23	n.a.*

*n.a.: not available
Source: Bradley

panel of experts. These methods assess environmental factors like political stability, economic growth, attitude toward foreign investment, and so forth. The panelists score each factor and the results are aggregated using different weights. The resulting index gives a measure of political risk of a country.

A second group of methodologies uses indices built on quantitative indicators. Several of these indices are available. One of the most sophisticated ones is the "Political System Stability Index" (PSSI) prepared by Haendel, West and Meadow. Rather than relying on "soft" opinion measures, the PSSI is based on "hard" data. PSSI is composed of three equally weighted indices, all of which include indicators bearing on the stability of the political system: (1) the Socioeconomic Index; (2) the Governmental Processes Index; and (3) the Societal Conflict Index.

Bhalla[4] published a foreign investment risk matrix prepared for 114 market-oriented countries. Each country was rated on a risk matrix for short and long term political and economic factors. Political risk was assessed in terms of the stability of the govern-

4 Bhalla's risk matrix was originally prepared for use in the packaging industry. However, the rating was generated, taking into account factors affecting the manufacturing sector in general. Thus, its employment to evaluate the aluminum industry is as legitimate as that of any other index available in the market at the time of the study.

ment, judged by the quality of the administration and the frequency of character of its change, and the legitimacy of each government evident in public attitude toward and support for its leaders and political institutions. Economic risk was measured by demographic structure, infrastructure, demand structure, and economic growth. While the authors do not claim total agreement with each entry, this source provides a measure of risk independent of the authors. The matrix with countries relevant to the aluminum model is given in Table 4.

Table 4

MATRIX OF COUNTRY RISK

Political	Economic			
	1.0	1.1	1.2	1.3
1.0	Japan W. Europe USA	Australia Canada		Jamaica
1.1	Greece	S. Africa Mexico	Malaysia	India Indonesia
1.2	Argentina Brazil Venezuela	S. Korea	Cameroun	Ghana Haiti Guinea Guyana Surinam S. Leone
1.3	Turkey Iran	Egypt	D. Republic	Zaire

Source: Bhalla

Since the decision on investment location in the Eastern bloc and China is, to a large extent, independent of international mining corporations, the existing and potential locations in those areas were assigned the lowest risk index of 1.0 (since investment there would be internal, that can be viewed as very low risk). The ranking of countries was obtained by multiplying the indices shown in Table 4 for both economic and political risk. To facilitate further handling of this parameter the resulting index was normalized, resulting in a ranking of countries with an index ranging from −8.35 to 8.75.

IV. Network Compromise Programming

Compromise programming provides a means of identifying expected investment given varying emphases upon cost and risk. A key concept used in this study is that of a nondominated solution. A solution is nondominated if no other solution has a preferable cost and risk result at the same time. The use of linear programming models will yield nondominated solutions when weighted combinations of a combined objective function are used (Zeleny, 1973).

A network flow model was run with objective function reflecting cost. This solution yielded the worst nondominated measure of risk. Then a series of models reflecting weighted combinations of the risk function and the cost function were run. It was necessary to use a weighted combination because a number of solutions yield the same risk. To assure nondominance, cost must be considered at least a small value to select between alternative low risk solutions. The risk function minimized was:

$$\text{Min } Z_r = \sum_{m=1}^{M} X_m{}^* \, \sigma_m C_{capm} + \sum_{r=1}^{R} X_r{}^* \, \sigma_r C_{capr} + \sum_{s=1}^{S} X_{sl}{}^* \, \sigma_x C_{caps} + \sum_{s=1}^{S} X_{sh}{}^* \, \sigma_s C_{caps}$$

where σ_m is the risk associated with mine m

σ_r is the risk associated with refinery r

σ_x is the risk associated with smelter s

C_{capm} is the capital cost per T at mine m (a component of C_m)

C_{capr} is the capital cost per T at refinery r (a component of C_r)

C_{caps} is the capital cost per T at smelter s (a component of $C_{sl}{}^*$ or $C_{sh}{}^*$)

The overall function minimized:

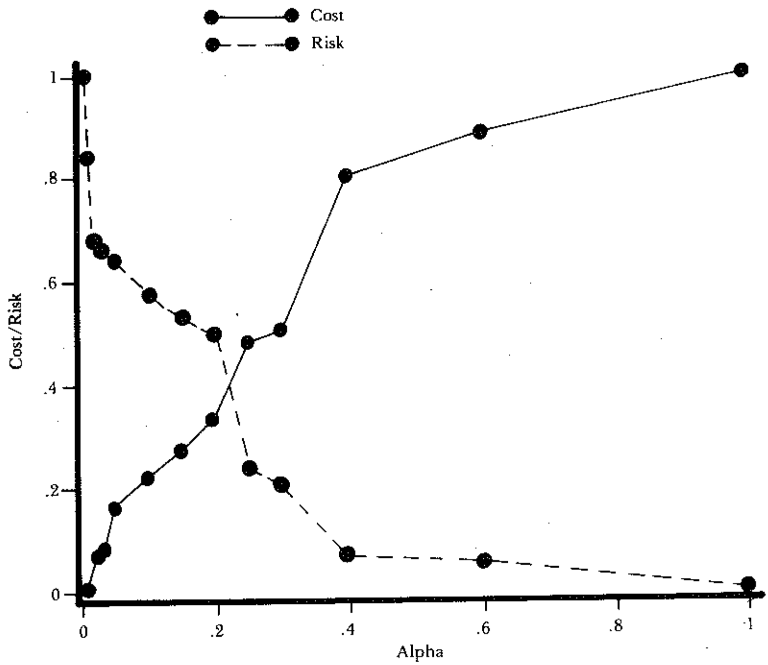
$$\text{Min } Z = (1\text{-}\alpha)Z_c + \alpha Z_r$$

where α is the risk weight ($0 \leqslant \alpha \leqslant 1.0$)

Once the cost minimization solution and the risk minimization solutions were obtained, the attainment of both objectives could be measured proportionately. Each intermediate solution can be evaluated in terms of the relative sacrifice of cost and risk between the two extreme solutions. Figure 2 presents the relative sacrifices of the two objectives at various levels of α. Those solutions selected were chosen to give a diverse representation of nondominated solutions. Note that there is no guarantee that equal sacrifice will occur at α of .5. This is because there usually will be differences in scaling. In addition, there is differential impact on the production processes of mining, refining, and smelting due to different proportional capital costs as well as marginal cost differences for specific solution variables.

Figure 2

RELATIVE SACRIFICES : COST/RISK



The advantage of using network flow models for this class of problem is simplicity of modeling as well as computational speed. A computer code was written to insert the weighted objective function reflecting selected α, reflecting the resulting cost and risk functions. Then this input file was optimized with a network optimizer. Additional computer codes interpreted the resulting solution, calculated resulting cost and risk, and generated a detailed report of all variables. This last report code also added the fixed costs for expanded facilities in order to check for severe impact of omitting the 0-1 constraints in the algorithm model. As all costs for rising were greater, no severely apparent impact was detected.

V. Results

The tradeoff between cost and risk minimization presents a contingent series of solutions rather than a single solution. The cost minimization solution given by the World Bank study provides an indication of potential for higher profit, although risk involved to investors was not considered. The solutions obtained in this study indicate that as risk becomes more important, investment sites other than low cost sites become more attractive. This is due in large part to the small marginal costs often associated with alternative investment sites. The argument of this paper is that investors would make a risk assessment based upon current conditions. If general economic and political conditions were stable, we would expect movement towards the cost minimization solution. On the other hand, if risk were more important due to turbulence, political or economic, we would expect a shift in investment toward less risky sites.

A. Actual Investment Patterns

The solutions obtained in this study reflect extremes at the cost minimization end (increased investment in LDCs) and the risk minimization end (increased investment in OECD). Varying the risk level yields a number of sites that do not appear in either extreme case. One measure of what is likely to occur is the increases in investment between 1970 and committed investments as of 1980. Mikessel observed that between 1966 and 1977, the book value of US investment in all mining and smelting operations in LDCs dropped from 42 percent to 32 percent of total US investment in mines and smelters. Within the aluminum industry, World Bank data indicates that the share of investment in LDCs was 34 percent for mining, 21 percent in refining, and 32 percent in smelting between 1970 and the committed investments as of their report date (initial report published in 1982). Detailed results of our model are given in the Appendix. Each sector is reviewed below. Proportionate shares for LDCs are displayed in Figure 3.

B. Mines

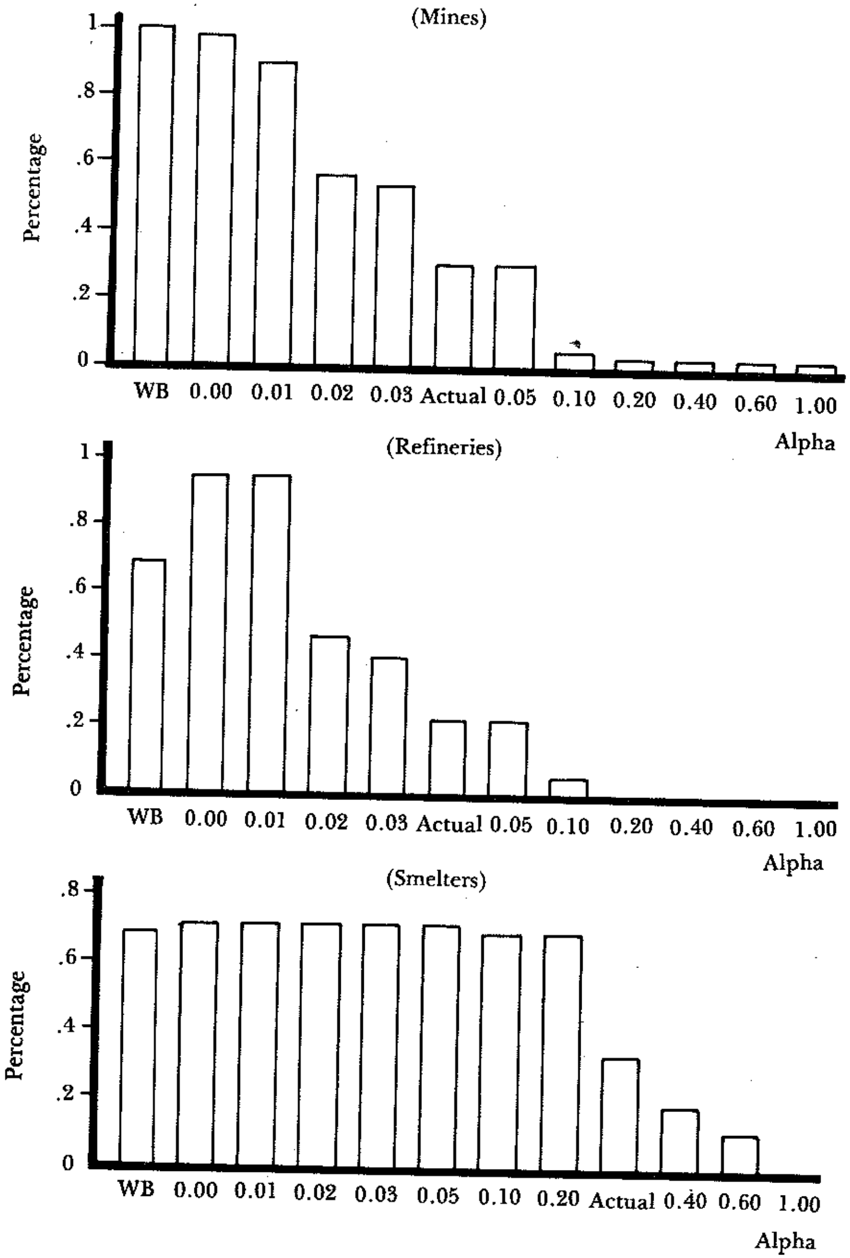
The cost solution is quite close to the World Bank's solution. Our model has higher capacity for the East European and Chinese mining sector, totalling 2 percent of total tonnage increased. Our model makes these locations highly attractive in essence, risk would drive investors out of the market, leaving a vacuum for these independent locations to fill as risk level increases. The greatest expansion expected in the cost models would be in Jamaica and Indonesia. Increasing the risk level does not yield a direct transition between extreme solutions. Compromise locations such as Venezuela and Brazil, with relatively low costs as well as risk in the model show increased capacity at lower levels of risk. A large proportion of the alternative investment shows up in Australia, which has abundant bauxite reserves, although at a cost disadvantage due to their high shrink ratio. At the risk minimization extreme, less economical Western European mines are increased by the model. The actual investment pattern in the last decade falls near the solution with α of .05. (The α level has no purported meaning other than order.)

C. Refineries

Refinery investment is characterized by high capital costs. While mining investment must follow available reserves, refineries could be sited anywhere. The model given by the World Bank would favor siting refineries at mine sites, primarily due to economic advantage in shipping rates. Bulk bauxite and alumina rates are modeled. There is significant volume saving available from shipping alumina rather than bauxite. The cost minimization solutions emphasize expansion in Jamaica, India, and ASEAN. As risk level is increased, Brazil, Venezuela, Korea, and Australia are assigned higher volumes. As risk level is increased to higher levels, the model assigns all new investment outside of LDCs. Actual investment in the last decade yields proportions

Figure 3

THIRD WORLD EXPANSION 1980 TO 2000



close to an α level of .05.

D. Smelters

Smelter investment involves consideration of additional factors. First, the model stresses the need to locate near low cost electrical sites. Second, shipping economies differ from that for refineries, in that, due to bulk shipping advantages for alumina unavailable for smelted aluminum, it is cheaper to locate smelters nearer demands. The World Bank forecast for demand increase shows 406 percent increase in demand in LDCs from 1980 to 2000, while a 185 percent growth in demand for the other sectors. Additionally, the method used for measuring risk utilized capital investment costs as the coefficient for the risk function, and capital cost for smelting is proportionately much less than that required for mining and refining. The solutions obtained were less affected by risk mining and refining. Canada (with a large cost advantage in electricity) and Australia are assigned increased capacities by the model as risk increases. Actual investment patterns over the last decade fall near an α level of .40. We would conclude that smelting would be less responsive to risk consideration than the mining and refining sectors.

VI. Conclusions

The World Bank study provides an excellent source of information concerning the world aluminum industry. That study recognized the existence of risk, but did not model risk because of the difficulty in developing risk factors compatible with their cost model. The conclusions given by the World Bank report reflect that lack of risk consideration. That report emphasized expected investment in developing countries.

This study utilized an independent measure of political risk, combining that risk rating with the World Bank cost model through compromise programming. The conclusions of this study are that various levels of risk will result in widely differing investment decisions on the part of investors. This varying investment behavior is not expected to involve a direct transition between a low cost solution and a low risk solution. Actual investment patterns indicate that investment in locations with moderate cost as well as moderate risk can be expected to receive the bulk of future investment in the growing primary aluminum industry.

The risk measure used in this study was selected as an independent ranking of risk by international finance professionals. It is expected that actual risk to investors would be dynamic, as well as varying by investor. But our point is that while cost minimization models identify economically efficient sites available for capacity increases, actual investment would be expected to be heavily influenced by political risk perception. This would likely lessen the proportion of investment in developing countries.

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