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Chapter Author: Frederick R. Demler, John E. Tilton

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FREDERICK R. DEMLER and JOHN E. TILTON

Modeling International Trade Flows in Mineral Markets

The trade pattern for refined tin, blister copper, bauxite, or any other mineral commodity can be described by a matrix, such as that shown below. Its elements, T_{ij}, indicate the quantity of the commodity shipped from country i to country j during the period under consideration. Total exports of the ith country (T_i^X) can be calculated from this matrix simply by summing the ith row ($\Sigma_{j=1}^{m} T_{ij}$), and the total imports of the jth country (T_j^M) by summing the jth column ($\Sigma_{i=1}^{n} T_{ij}$). Total world trade in the commodity (T) is the sum of all elements ($\Sigma_{i=1}^{n} \Sigma_{j=1}^{m} T_{ij}$).

$$
\begin{array}{ccccc|c}
T_{11} & T_{12} & \cdots & T_{1j} & \cdots & T_{1m} & T_1^X \\
T_{21} & T_{22} & \cdots & T_{2j} & \cdots & T_{2m} & T_2^X \\
\vdots & \vdots & & \vdots & & \vdots & \vdots \\
T_{i1} & T_{i2} & \cdots & T_{ij} & \cdots & T_{im} & T_i^X \\
\vdots & \vdots & & \vdots & & \vdots & \vdots \\
T_{n1} & T_{n2} & \cdots & T_{nj} & \cdots & T_{nm} & T_n^X \\
\hline
T_1^M & T_2^M & & T_j^M & & T_m^M & T
\end{array}
$$

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The trade patterns described by the above matrix are important. A country's choice of trading partners may facilitate or impede its access to markets if the country is an exporter or to available raw material supplies if it is an importer. Despite this fact, traditional trade literature has paid little attention to trade patterns. Classical, neoclassical, factor endowment, and the more recent theories of trade that take into account the creation and the diffusion of new technology as well as other dynamic variables all concentrate on explaining comparative advantage, that is, why countries are net importers or exporters of various commodities. The question of trade patterns is often bypassed by assuming that the world is composed of only two countries or two regions. Where this is not true, transportation costs and other factors shaping the flow of trade are generally ignored in order to simplify the analysis.

Outside the mainstream of the international trade literature, location theorists have for many years emphasized the importance of transportation costs and stressed the influence that such costs have on both trade patterns and the overall level of exports and imports. Their studies, however, have usually ignored the influence that political blocs, international ownership ties, product differentiation, and other factors besides transportation costs have on trade patterns. Just why this is so is far from clear, for even a cursory look at the structure of trade for many commodities suggests that such factors are important.

Location studies such as the more traditional trade literature generally presume that trade flows are flexible and thus can be easily altered to accommodate new sources of supply, new sources of demand, changes in transportation costs, and shifts in comparative advantage in production. But if other factors, such as political blocs and ownership ties are important, this may not be a valid assumption.

This chapter describes research conducted over the last several years on trade patterns in a number of mineral industries. The next section examines a simple econometric model that has been used to identify the major factors shaping trade flows and to assess the relative importance of these factors. The third section summarizes the principal findings of previous studies that have applied this model to analyze trade patterns in aluminum, bauxite, copper, iron ore, and nickel. The fourth and fifth sections report on the latest application of the model to explain world trade in tin and zinc. The sixth and final section examines the implications of the findings for the resource and trade policies of mineral producing and exporting countries in Latin America and elsewhere.

THE MODEL

In the early 1960s, Tinbergen (1962: appendix VI) and Linnemann (1966) working in the Netherlands and Poyhonen (1963) and Pulliainen (1963) working in Finland developed a model, now known as the structure of trade model, to analyze aggregate trade flows between countries. Their efforts involved the compilation of trade matrices, similar to that described earlier, that encompassed total trade between countries rather than only trade in a single commodity. They then explained trade flows on the basis of export-supply factors in exporting countries, import-demand factors in importing countries, and the resistance to trade between exporting and importing countries as determined by distance and other considerations.

The model used here to analyze trade in mineral commodities is based on these early efforts to explain aggregate trade flows.[1] In its simplest form, it consists of a single relationship whose parameters are estimated by classical least squares regression analysis. The dependent variable (T_{ij}) is the quantity of a mineral commodity shipped between various pairs of importing and exporting countries as reflected in the trade matrix for the commodity. This variable is assumed to be a linear function of: (1) the potential of country i to export the mineral commodity (XP_i), (2) the potential of country j to import the mineral commodity (MP_j), and (3) the resistance to trade between country i and country j (R_{ij}). In equation form this relationship can be expressed:

$$T_{ij} = a_0 + a_1 XP_i + a_2 MP_j + a_3 R_{ij} + e_{ij} \qquad (5\text{–}1)$$

where the a's are parameters and e_{ij} is the disturbance term.

The potential of country i to export the mineral commodity is presumed to depend on the country's capacity to produce the commodity (P_i) minus some fraction (b_1) of its capacity to use the commodity (U_i). That is:

$$XP_i = P_i - b_1 U_i \qquad \text{where } 0 \leq b_1 \leq 1 \qquad (5\text{–}2)$$

If government regulations, ownership ties, or other factors dictate that domestic needs for the mineral commodity be satisfied before exports are permitted, b_1 is equal to one. At the other extreme, if domestic consumers have no preferential access to domestic production, the export potential of a country is equal to its production capacity, and b_1

is equal to zero. If some but not total preference is shown domestic consumers, b_1 will be positive but less than one. The value of b_1 can be determined on the basis of a priori information or it can be estimated by the model itself.

Since the jth country imports the mineral commodity, its capacity to use the commodity (U_j) is likely to exceed its capacity to produce the commodity (P_j). In this case, its potential to import can be estimated by the expression

$$MP_j = U_j - b_2 P_j \qquad \text{where } 0 \leq b_2 \leq 1 \tag{5–3}$$

The parameter b_2 should equal one if domestic consumers for one reason or another buy from foreign producers only after domestic production is exhausted. Alternatively, if domestic producers must compete equally with foreign producers for the domestic market, b_2 is zero. If some but not total preference is given to domestic producers, b_2 will be positive but less than one. Like b_1, this parameter can be determined by a priori information or it can be estimated by the model.

A number of factors may increase or decrease the resistance to trade between countries. In this regard, the distance between two countries (D_{ij}) has already been mentioned. Since transportation costs tend to rise with distance, this variable should inhibit trade. Alternatively, membership in the same political bloc (B_{ij}), such as the British Commonwealth, the French Community, or the European Economic Community, would be expected to stimulate trade between the two countries. Similarly, when multinational corporations based in the importing country own production facilities in the exporting country, ownership ties (O_{ij}) may promote trade.

There is also some evidence that, if two countries are neighbors (N_{ij}) in the sense of sharing a common border, their trade tends to be larger than expected even after taking into account the short distance between them. Among the possible reasons for this is the fact that businessmen are more likely to be familiar with the language, customs, business traditions, and consequently the commercial opportunities available in neighboring countries than in more distant states.

Another factor that may stimulate trade between two countries is product differentiation (S_{ij}). Mineral ores and concentrates, for example, may contain difficult impurities or valuable by-products that only certain smelters can remove. An interesting example is found in copper concentrate trade. The Philippines, which ships most of its output to Japan for smelting, has for years sent a significant quantity of concentrates to the United States despite high transportation costs. This unusual trade flow arose and has continued simply because Tacoma, Washington, has one of the few smelters in the world that can treat the high arsenic copper ores found in the Philippines. Similarly, there are differences in the nature and composition of bauxite ores. Alumina refineries are designed to handle a particular type of bauxite and can be modified only at some expense to handle other types of ores.

Finally, in some applications of the trade model long-term contracts (L_{ij}) covering the sale of the mineral commodity from country i to country j are considered. Whether long-term contracts should be included in the model depends on the nature of the questions being addressed. If one is primarily interested in determining the extent to which trade flows are flexible, and thus can be quickly and easily altered to accommodate new sources of supply or demand, the effects of long-term contracts ought to be taken into account. Alternatively, if the primary objective is to identify the fundamental factors shaping trade and to appraise their relative importance, long-term contracts should not be included, for they are for the most part merely the result or consequence of more basic determinants of trade patterns.

The preceding identifies all of the factors that have been explicitly incorporated into the trade model to date. In new applications, other variables may be important, and the model can easily be modified to take account of the effects of these variables as well.

If one includes all of the above variables and assumes that the influences of these variables are independent and additive, resistance to trade (R_{ij}) between any two trading partners can be measured.

$$R_{ij} = c_1 D_{ij} + c_2 B_{ij} + c_3 O_{ij} + c_4 N_{ij} + c_5 S_{ij} + c_6 L_{ij} \qquad (5\text{–}4)$$

Substituting Equations 5–2, 5–3, and 5–4 into Equation 5–1 gives the following relationship, which can be estimated.

$$T_{ij} = d_0 + d_1(P_i - b_1 U_i) + d_2(U_j - b_2 P_j) + d_3 D_{ij} + d_4 B_{ij} + d_5 O_{ij} + d_6 N_{ij} + d_7 S_{ij} + d_8 L_{ij} + e_{ij} \qquad (5\text{–}5)$$

In this equation dummy variables must be used for B_{ij}, N_{ij}, and S_{ij}, which take the value of one when countries i and j belong to the same political bloc, are neighbors, or have special ties due to product differentiation, and which take the value of zero otherwise.[2] However, the effect on trade of these variables is likely to vary depending on the maximum trade possible (M_{ij}) between the two countries. One would expect, for example, that common membership in the British Commonwealth should stimulate imports into Britain from a large exporting country more than from a small exporting country.

For this reason, it is more appropriate to use slope dummy variables, rather than level dummy variables, as shown in the following modification of Equation 5–5

$$T_{ij} = d_0 + d_1(P_i - b_1 U_i) + d_2(U_j - b_2 P_j) + d_3 D_{ij} + d_4 B_{ij} M_{ij} + d_5 O_{ij} + d_6 N_{ij} M_{ij} + d_7 S_{ij} M_{ij} + d_8 L_{ij} + e_{ij} \quad (5\text{–}6)$$

Here the maximum possible trade (M_{ij}) between country i and country j can be estimated by the export potential of country i or the import potential of country j, whichever is smaller. That is,

$$M_{ij} = XP_i, \text{ if } XP_i \leq MP_j$$
$$= MP_j, \text{ if } XP_i \geq MP_j$$

Equation 5–6 measures only the direct effects of the various independent variables on trade flows although these variables may also have important indirect effects. For example, the incidence of ownership ties between two countries may be influenced by the distance that separates them. This appears to have been the case in bauxite, at least in the 1950's when North American producers built bauxite facilities in a number of Caribbean and South American countries while the major European producers invested in mines in Europe and Africa. In this case, distance in addition to its direct effect on trade also appears to have influenced trade indirectly through ownership ties.

The basic model given in Equation 5–6 can be modified in two ways to assess the indirect effects of independent variables. First, in the case just cited, the equation could be rerun without the ownership tie variable. The new coefficients obtained for distance and any other independent variable thought to influence ownership ties could then be compared with those obtained when the ownership tie variable is included in the model. Second, the model can be enlarged in a recursive manner. A second equation could be introduced to explain the incidence of ownership ties between country i and country j as a function of the distance between the two countries and other factors. Similarly, equations could be included in the model to explain other independent variables, such as the exporting country's production capacity, the importing country's capacity to use the mineral product, and long-term contracts.

The trade model described in this section does have certain limitations that should be noted. In particular, it assumes that the relationship between trade flows and the various determinants of these flows is linear. If this is not the case, the model suffers from specification error. Much of the work noted earlier on aggregate trade flows assumes a multiplicative rather than linear relationship. In some respects a multiplicative relationship is appealing, because if either the export potential of country i or the import potential of country j is zero, trade between the two countries should be zero as the multiplicative relationship would dictate. However, the latter also requires that trade between two countries be zero when resistance to trade is zero, which is not what one would expect. Moreover, when the structure of trade model is applied to individual commodities, trade flows between some pairs of importing and exporting countries can be zero, and they usually are. Since the logarithm of zero is undefined, when this is the case, the parameters of a multiplicative relationship cannot be estimated by a linear transformation of this relationship. This complicates the estimation procedure. Thus, in the absence of strong a priori reasons favoring the multiplicative relationship, the linear relationship was chosen for practical considerations. In making this decision, however, the analysis presumes that such a relationship is a close approximation to the true relationship over the range of variable values considered.

A second shortcoming is that the model can produce results that are internally inconsistent in the sense that the expected trade flows predicted by the model when summed may exceed the export or import potential of certain countries. In addition, expected trade flows may in some cases be negative. Such inconsistencies are particularly disconcerting if the model is to be used to project individual trade flows. They are less of a problem when the objective is to appraise the importance of various factors influencing trade patterns.

It should also be noted that the model is in a sense a reduced form model. Ideally, in analyzing trade flows one would like a model that encompasses separate supply and demand models for each country and then integrates these models by taking into account shipping costs, political blocs, ownership ties, neighboring country effects, and other relevant considerations. The difficulty with this approach, however, is that it requires accurate information on production costs and prices by country for the commodity being analyzed. This information is always difficult and frequently impossible to obtain. In the simpler model used here this information is not needed for the effects of production costs and prices on trade patterns are taken into account by the export potential and import potential variables. As a result, this model is far easier to apply.

APPLICATIONS

In recent years, the model described in the previous section, or a variation of it, has been used to investigate international trade in aluminum (Dorr, 1975; Tilton and Dorr, 1975), copper (Whitney, 1976), iron ore (Santos, 1976), and nickel (Hubbard, 1975). These studies examine trade at fixed time intervals over the postwar period, and with the exception of the study on iron ore, at various stages of processing.[3] A comparison of these findings provides some insights into the important factors shaping international trade patterns and how these factors vary from one mineral commodity to another, by stage of processing, and over time.

Table 5–1 identifies the independent variables considered by these studies for various mineral commodities for the years 1955 and 1972. It also denotes the variables found to be significant determinants of trade patterns with an 'S' and those found to be insignificant with an 'I'. The omission of a variable from a model, indicated by a blank in the table, generally implies that it is irrelevant to the analysis. For example, for some commodities none of the major importers and exporters are neighbors or belong to the same political bloc.

All of these studies find that ownership ties, and the multinational resource companies that are largely responsible for international ownership ties, greatly influence trade flows at least at one stage of production. However, there has been some decline over time in the importance of ownership ties for certain mineral commodities, particularly refined copper. The reasons for this are not hard to identify. First, in copper and iron ore as well, a number of important facilities have been nationalized over the last decade. There have also been instances of nationalization in the aluminum and nickel industries, but such incidents have been fewer and less important. Second, the nature of financing new mineral ventures has evolved in a way that has loosened the ties of ownership on trade. In the early postwar period, multinational resource companies typically owned completely the foreign operations they developed and managed. In the 1960s this began to change as many firms turned increasingly to project financing. Joint ventures became more prevalent, and debt capital was used more heavily. Long-term contracts were arranged to assure a market for the output of new projects, and at times the collection rights to these contracts were pledged or sold to raise funds. Third, Japan, a country that has relied more on long-term contracts and less on ownership ties than the United States and Western European countries to assure access to raw material supplies, has become increasingly important in mineral trade. Despite these developments, however, ownership ties remain a

Table 5–1. Results of Recent Studies Concerning the Determinants of Trade Patterns

Commodity	*Export Potential* 1955	*Export Potential* 1972	*Import Potential* 1955	*Import Potential* 1972	*Distance* 1955	*Distance* 1972	*Ownership Ties* 1955	*Ownership Ties* 1972	*Political Blocs* 1955	*Political Blocs* 1972	*Neighboring Countries* 1955	*Neighboring Countries* 1972	*Long-Term Contracts* 1955	*Long-Term Contracts* 1972
Bauxite	I[a]	I[a]	I[a]	I[a]	I[a]	I	I[a]	S	S					S
Alumina[b]	I[a]	I[a]	I	I	I	I[a]	S	S						S
Aluminum	S	S	I[a]	S	I	S	I	I	S[c]	S[c]	S	S		
Copper Concentrate[d]	I	S	S	S	S	S	I	I			I	I		
Blister Copper[d]	S	I	I	I	I[a]	I	S	S	S[e]	S[e]				
Refined Copper	I	S	S	S	I	I	S	I	S[f]	S[g]	S	S		
Iron Ore[h]	S	S	S	S	S	S	S	S			S	S		S
Refined Nickel	I[a]	I[a]	I[a]	S	I[i]	S			S[j]	S[j]	S[k]	S[k]		

Sources: Dorr (1975); Hubbard (1975); Santos (1976); and Whitney (1976).

"S" indicates that the variable is statistically significant at the 95 percent probability level (using a one-tailed t-test), "I" indicates that it is insignificant. A blank means that the variable was not included in the model. In most such cases, the variable was not a relevant factor affecting trade patterns for that commodity.

[a]This is a significant variable in the modified model that includes only export potential, import potential, and distance, which suggests that this variable may have an indirect influence on trade patterns by affecting ownership ties and other independent variables not included in the modified model.

[b]The information shown for alumina under 1955 is for 1960. Very little trade in alumina took place before 1960.

[c]The variable for the British Commonwealth is significant, whereas that for the European Economic Community is not.

[d]The information shown for copper concentrate and blister under 1955 is for 1960. Models for copper concentrates and blister were not estimated for 1955.

[e]The variable for Belgium and Zaire is significant, whereas those for the British Commonwealth and the European Economic Community are not.

[f]The variable for the British Commonwealth is significant, whereas that for Belgium and Zaire is not.

[g]The variables for the British Commonwealth and the ties between Belgium and Zaire are significant, whereas the European Economic Community is not.

[h]The information shown for iron ore under 1972 is actually for 1973.

[i]This variable is, however, significant at the 90 percent probability level.

[j]The variables for the British Commonwealth and the French Community are both significant for 1972. They are insignificant in 1955 at the customary 95 percent probability level, but are significant at the 90 percent probability level.

[k]In the refined nickel model the neighboring country effect was restricted to trade between the United States and Canada.

potent force shaping the structure of mineral trade. Indeed, in bauxite and alumina trade this variable is by far the dominant factor affecting trade flows, and there is little to suggest that its importance is waning over time.

Multinational resource companies are generally vertically integrated from mining through refining. Many of these companies are also active in fabrication, but at this stage of production they compete with many independent and nonintegrated producers. Since the sales of refined metal to the latter are not likely to be dictated by ownership ties, one would expect to find the influence of ownership ties on trade of less importance at the refined stage than at earlier stages of production. While this is the case for aluminum and nickel, copper is an exception. The copper concentrate that enters international trade is primarily produced by nonintegrated producers and thus is little affected by ownership ties.

The importance of ownership ties also varies with the mineral commodity. In aluminum and steel, where most of the value added in production comes in processing rather than in mining, the major firms in the industrialized countries have established subsidiaries abroad to insure an adequate supply of ore for their domestic processing plants. Consequently, ownership ties are a particularly important determinant of trade flows in these industries at early stages of processing. In the two other industries where mining accounts for a much larger share of the total value added, ownership ties are instrumental in shaping trade flows for unprocessed nickel and blister copper, but not, as just noted, for copper concentrates.

Political blocs have also been identified as important determinants of the structure of mineral trade. Unlike ownership ties, however, they have little or no influence on trade in ores and concentrate. Instead, their impact is largely on trade in refined products. The reason for this, presumably, is the fact that most mineral importing countries impose few, if any, barriers to trade on ores and concentrates. This is not the case for refined products.

Interestingly, the political blocs found to be important are all based on former colonial empires, such as the British Commonwealth, the French Community, and Belgium's ties with Zaire, the former Belgium Congo. In contrast, no significant increase in mineral trade has been detected among member states of the European Economic Community. Since the colonial empires on which the significant political blocs were built have been dismantled over the last twenty years, one would expect the influence of these blocs on trade to have diminished. The studies that have been done, however, find very little evidence of this.

In all of the refined mineral products examined, political blocs were important in the early postwar period and remain important today. Apparently, once strong commercial ties are established in mineral markets, they tend to perpetuate themselves for many years.

Only the studies analyzing iron ore, bauxite, and alumina trade explicitly include long-term contracts in their trade models. In all three of these cases, long-term contracts were of negligible importance during the 1950s. However, during the 1960s long-term contracts became more common, and thus by the 1970s such arrangements constituted a significant determinant of trade patterns. To some extent this development occurred because of the growth of Japan's imports of mineral commodities, particularly unprocessed minerals. As already noted, this country has opted to satisfy its raw material requirements through long-term contracts rather than develop its own subsidiaries abroad. In addition, as project financing and other developments have reduced the role of ownership ties elsewhere, long-term contracts have grown in importance as a means of assuring producers a market and consumers an adequate supply of mineral resources.

Sharing a common border has also been found to stimulate trade significantly among neighboring countries, particularly in refined metals, but in iron ore as well. Since fabricators tend to be smaller and more numerous than firms engaged in smelting and refining, they are more likely to concentrate on domestic markets and those in neighboring countries for their raw material supplies. For this reason, presumably, the neighboring country effect is a significant factor in aluminum, refined copper, and refined nickel trade, whereas it apparently has little influence on trade patterns in bauxite, alumina, copper concentrate, and blister copper. Moreover, despite the great improvements in international communications that have occurred over the postwar period, there is little indication that the effect of this variable on trade in refined commodities is abating.

Little can be said yet about the importance of special ties arising from product differentiation, for the studies that have been completed to date have not included this variable in their trade equation. In some instances, such as those noted earlier concerning the high arsenic, copper concentrate mined in the Philippines and the various types of bauxite, these studies have tried to assess the importance of such special ties qualitatively. However, the first attempt to introduce this factor explicitly into the trade equation is described in the next section.

The last variable that the previous section identifies as an influence on the resistance to trade between countries is distance. One would expect distance to have a greater impact on the trade patterns of ores and concentrates than of refined metals since transport costs constitute a larger percentage of the total value of the former. The copper study provides some support for this hypothesis, but the aluminum study does not. Moreover, while distance is a significant factor influencing trade flows in iron ore, the same is also true for refined nickel. For similar reasons, distance should be a more important determinant of trade patterns of mineral commodities with a relatively low value. On this basis, one would expect to find distance more influential in copper and aluminum trade than nickel trade, but this is not the case. The impact of distance can also be seen as declining, because of the sharp fall in transportation costs. This cost decrease is a consequence of increases in vessal size and technological advances in vessals as well as in supporting infrastructure and overland transportation. But here again the evidence is far from clear and consistent.

Part of the problem lies in the fact that distance, although a statistically significant factor in many instances, is simply not a major determinant of mineral trade patterns compared to ownership ties and other factors. The same is also true, perhaps more surprisingly, for export and import potential. All of the studies employing the trade model of the previous section estimate a modified version of Equation 5–6 that includes only the export potential, import potential, and distance variables. The results are compared with those obtained when ownership ties, political blocs, the neighboring country effect, and long-term contracts are included in Equation 5–6. In few cases does the modified model account for or explain more than 30 percent of the variation in trade flows among the major importing and exporting countries, even though this specification of the model considers both the direct and indirect effects of these three variables on trade flows. In contrast, the full equation often explains over 80 percent of the variation in trade flows, and only for copper concentrate trade does this figure fall below 60 percent.

Thus, the studies that have been conducted on mineral trade patterns to date consistently find that these patterns cannot be adequately explained simply on the basis of export potential, import potential, and distance alone. The other factors that shape trade flows may vary from one mineral commodity to another, by stage of processing, and over time, but as a group they have a major impact on the direction of trade of all the mineral commodities examined. Moreover, these factors—ownership ties, political blocs, neighboring country effects, and long-term contracts—all introduce a degree of stability and rigidity in mineral trade patterns, and so may make it more difficult for new importers or new exporters to break into the market.

INTERNATIONAL TRADE IN TIN

Tin is an unusual metallic commodity in several respects. Though underground mining is important in certain areas, such as Bolivia, most tin is recovered from alluvial deposits. For this and other reasons, tin-producing firms are far more numerous and generally much smaller than the firms found in other metal industries. Consequently, the multinational resource companies are much less important in this industry, and the incidence of international ownership ties is less widespread.

These aspects of the tin industry raise the possibility that a different set of factors govern trade patterns in this industry. To determine if this is the case, the trade model described above has recently been employed to analyze trade flows in tin. The results of this investigation, which have not been reported elsewhere, are discussed in this section. Since tin enters international trade in the form of concentrates and refined metal, the pattern of trade is examined at each of these stages of production.

Tin Concentrate Trade

Trade matrices indicating the average annual quantity of tin concentrate trade over three-year periods centered on 1955, 1965, and 1975 are shown in Table 5–2. These matrices identify the trade flows between the major exporting and importing countries outside the Communist bloc. Trade among the Communist countries is excluded since it presumably is shaped by a different set of forces. Trade flows between minor exporting and importing states, which in Table 5–2 are aggregated under the category of "other," are also excluded from the analysis since their contribution to tin trade is small.

In the tin concentrate model, trade between the major exporting and importing countries (T_{ij}) as shown in Table 5–2 is assumed to depend on the following variables:

1. The export potential of country i (XP_i). Because it is difficult to obtain reliable information on the mine capacities of tin-exporting countries, this variable is estimated by the largest annual quantity of tin concentrate exports from country i over the preceding five years measured in thousands of metric tons of contained tin.[4]

2. The import potential of country j (MP_j). For similar reasons, this variable is estimated by the largest annual volume of tin concentrate imports into country j over the preceding five years measured in thousands of metric tons of contained tin.[5]

3. The ocean distance between country i and country j (D_{ij}) in

Table 5–2. Trade in Tin Concentrates (Thousands of Metric Tons of Contained Metal)

				1955			
	United Kingdom	United States	Malaysia	Benelux	Netherlands	Germany	Other[a]
Indonesia		5.53			26.75	0.53	0.68
Bolivia	16.50	10.10					
Zaire	0.40	0.60		10.50			0.30
Thailand		1.80	9.92				0.40
Nigeria	8.50						
Other[a]	0.91	0.15	0.81			0.03	2.01
				1965			
	United Kingdom	United States	Malaysia	Benelux	Netherlands	Germany	Other[a]
Indonesia			15.10		17.20		
Bolivia	16.57	6.29			0.63	1.56	
Zaire	0.16			3.10	0.47		
Australia	0.53		0.55		0.40		0.57
Other[a]	1.54	0.07	0.59	1.43	4.30		0.14
				1975			
	United Kingdom	United States	Malaysia	Benelux	Spain	Germany	Other[a]
Indonesia			7.70		0.50		
Bolivia	7.27	7.00		0.15	1.46	2.20	1.36
Zaire				2.79	1.00		
Rwanda				1.12			
Australia	0.72		3.57		0.94		0.13
Burma			2.40	0.16	0.03		0.21
Republic of South Africa	0.72			0.03	0.28		
Other[a]	0.95	0.40	0.60		0.60		3.00

Sources: International Tin Council (various years); *Metal Statistics* (various years).

[a] Figures reported for "other" countries are estimates.

thousands of nautical miles, as reported by the U.S. Naval Oceanographic Office (1965).

4. A dummy variable (S_{ij}) to take account of the unusual nature of Bolivian ore. Compared with tin mined in the rest of the world, which comes mostly from alluvial deposits and so is relatively clean, Bolivian ore is difficult to refine. This is both because it contains impurities that require complex metallurgical processes to remove and because it contains valuable by-products that must be separated from the ore in a way that permits their economic recovery. Outside of Bolivia, only a few refineries that can process this country's ore exist. These facilities are found in the United States, the United Kingdom, and the Netherlands. To capture this constraint on Bolivian tin concentrate trade, S_{ij} takes the value of one if country i is Bolivia and if country j possesses a tin refinery capable of processing Bolivian concentrates. Otherwise, it is zero.

Since the stimulating effect of this variable on trade when it is equal to one will depend on the maximum amount of trade (M_{ij}) possible between countries i and j, S_{ij} is multiplied by M_{ij}. The latter is assumed to equal XP_i or MP_j, whichever is smaller.

5. A dummy variable for the neighboring country effect (N_{ij}), which assumes the value of one if country i and country j share a common border and zero otherwise. This variable is also multiplied by the maximum amount of trade (M_{ij}) possible between two countries.

6. Three dummy variables for political blocs. The first ($B1_{ij}$) takes the value of one for trade flows between Benelux and Zaire; the second ($B2_{ij}$) for trade flows between the United Kingdom and members, or former members, of the British Commonwealth; and the third ($B3_{ij}$) for trade flows between the Netherlands and Indonesia. These variables are all multiplied by the maximum amount of trade possible (M_{ij}) between the exporting and importing countries.

7. A dummy variable for ownership ties (O_{ij}) that takes the value of one when an appreciable portion (30 percent or more) of the tin mine capacity in country i is owned by interests in country j.[6] Again, this variable is multiplied by the maximum amount of trade (M_{ij}) possible between two countries.

The coefficients for the tin concentrate equation are shown in Table 5–3 for both the full model and a modified model that includes as independent variables only the export potential of country i, the import potential of country j, and distance between countries. This table also indicates the coefficient of determination (R^2) and the number of observations (n) for each equation.

The modified model is estimated for two reasons. First, by comparing the coefficients of the export potential, import potential, and dis-

Table 5–3. Results of the Tin Concentrate Model

	Constant	D_{ij}	XP_i	MP_j	$S_{ij}M_{ij}$	$N_{ij}M_{ij}$	$B1_{ij}M_{ij}$	$B2_{ij}M_{ij}$	$B3_{ij}M_{ij}$	$O_{ij}M_{ij}$	R^2	*n*
	1.370[a]	−0.216[a]	0.059[a]	0.076	0.559[a]	0.625[a]	0.568[a]	0.169	. . .	0.017	0.91	42
1975	(0.454)	(0.049)	(0.019)	(0.026)	(0.057)	(0.081)	(0.162)	(0.507)		(0.495)		
	2.176[a]	−0.408[a]	0.157[a]	0.039								
	(0.912)	(0.095)	(0.035)	(0.053)							0.52	42
	2.701	−0.305	0.019	−0.033	0.318[a]	0.653[a]	. . .	0.234	0.212	0.425	0.78	24
1965	(2.627)	(0.291)	(0.056)	(0.091)	(0.112)	(0.225)		(1.56)	(0.684)	(0.658)		
	1.453	−0.616[a]	0.153[a]	0.191[a]							0.38	24
	(3.235)	(0.337)	(0.066)	(0.107)								
	2.511	−0.343	0.016	−0.013	0.308[a]	0.083	0.476	0.136	0.670[a]	0.252	0.79	30
1955	(1.678)	(0.213)	(0.053)	(0.054)	(0.074)	(0.252)	(0.291)	(0.256)	(0.212)	(0.187)		
	−0.801	−0.421	0.155[a]	0.163[a]							0.17	30
	(2.652)	(0.320)	(0.082)	(0.080)								

Source: Based on the authors' computations.

[a]Significant at the 95 percent probability level, one-tailed test.

tance variables obtained for this model with those for the full model, one can assess the magnitude of the indirect effects that these variables have on the structure of tin concentrate trade through ownership ties, political blocs, and other independent variables found only in the full model. Second, by subtracting the coefficient of determination (R^2) for the full equation from that for the modified equation, one can appraise the marginal contribution of the neighboring country effect, political blocs, ownership ties, and the differentiated nature of Bolivian concentrates in explaining the trade flows shown in Table 5–2.

The results found in Table 5–3 indicate that the percentage of variation in trade flows that can be accounted for by export potential, import potential, and distance alone has increased from 17 percent in 1955 to 52 percent in 1975. Over the same period, the additional explanation of trade flows obtained by taking into account the differentiated nature of Bolivian ore, the neighboring country effect, political blocs, and ownership ties has fallen from 62 to 39 percent. Even though the combined effect of these latter variables has declined over the last twenty years, they still retain a substantial influence over the pattern of tin concentrate trade.

Looking at the coefficients for the individual variables affecting resistance to trade between countries, one finds that all of these coefficients have the expected sign, though some are not significantly different from zero at the 95 percent probability level. This is the case, for example, for the coefficients of the ownership tie variable and the political bloc variable for the British Commonwealth. The variable reflecting political ties between the Netherlands and Indonesia is significant only in 1955, and that for Benelux and Zaire only in 1975. In contrast, the differentiated nature of Bolivian ore is significant over the entire period, and the neighboring country effect from 1965 on. The coefficient for distance tends to fall in absolute value over the period, suggesting that the inhibiting effect of this variable on trade may be declining; however, the coefficient is significant only in 1975.

When these findings are compared with those of earlier studies on bauxite, copper concentrate, unprocessed nickel, and iron ore, political blocs appear more important and ownership ties less important in shaping trade in tin concentrate than is the case for the other mineral commodities, with the one exception of copper concentrates where ownership ties are unimportant. In addition, except for iron ore, the earlier studies do not find the neighboring country effect to be an important determinant of trade flows. Since firms producing tin concentrate tend to be smaller than their counterparts in other metal industries, it would not be surprising if they sold most of their output in nearby markets. Moreover, this variable, which helps explain the relatively large exports of Thai and Indonesian tin concentrates to Malaysia, may also be picking up the effects of product differentiation because the tin mined in Thailand and Indonesia, like that in Malaysia, comes from alluvial deposits and hence can be easily processed in the Malaysian refineries. This coupled with the importance of the variable reflecting the unusual nature of Bolivian tin suggests that the effects of product differentiation are more important for trade in tin concentrates than for most other mineral commodities.

Refined Tin Trade

Trade matrices showing the average annual quantity of refined tin trade over three-year periods centered on 1955, 1965, and 1975 are found in Table 5–4. These matrices, like those in Table 5–2 for tin concentrates, identify the trade flows between the major exporting and importing countries outside the Communist bloc.

The refined tin model assumes that trade between these countries (T_{ij}) as shown in Table 5–4 depends on many of the same variables found in the tin concentrate model:

1. The export potential of country i (XP_i), as indicated by that country's largest annual volume of refined tin exports over the preceding five years measured in thousands of metric tons.[7]

2. The import potential of country j (MP_j), as indicated by that country's largest annual volume of refined tin imports over the preceding five years again measured in thousands of metric tons.[8]

3. The ocean distance between country i and country j (D_{ij}) in thousands of nautical miles, as reported by the U.S. Naval Oceanographic Office (1965).

4. The dummy variable for the neighboring country effect (N_{ij}), multiplied by the maximum amount of refined tin trade possible (M_{ij}) between country i and country j. Again, M_{ij} is assumed to be equal to XP_i or MP_j, whichever is smaller.

5. The three dummy variables for political blocs. The first ($B1_{ij}$) covers the special ties between Benelux and Zaire; the second ($B2_{ij}$) the special ties between the United Kingdom and other members, or former members, of the British Commonwealth; and the third ($B3_{ij}$) the special ties between the Netherlands and Indonesia. All of these variables are multiplied by the maximum amount of trade possible (M_{ij}) between countries.

6. The dummy variable for ownership ties (O_{ij}), which takes the value of one when an appreciable portion (30 percent or more) of the refinery capacity in country i is controlled by interests in country j, and the value of zero otherwise.[9] This variable, like the other dummy variables, is multiplied by the maximum amount of trade possible (M_{ij}) between countries.

In addition to the preceding variables, which are all included in the tin concentrate model, the refined tin model contains:

7. A dummy variable ($B4_{ij}$) that takes the value of one when country i and country j are both members of the European Economic Community, and zero otherwise. This variable is also multiplied by the maximum amount of trade possible (M_{ij}) between countries.

8. A dummy variable (P_{ij}) to reflect the strong apparent preference of tin users in the United States for Malaysian tin. This variable takes the value of one when country j is Malaysia and country i the United States, and it is zero in all other instances. It too is multiplied by the maximum amount of trade possible (M_{ij}) between countries.

In competing for Malaysian tin, which has a reputation for high quality, the United States does not appear to have any particular advantage over other importing countries. It simply is willing to pay the price necessary in the competitive Straits tin market to acquire a large share of the output of Malaysian tin. Consequently, the special trading tie that the American preference for Malaysian tin has created between the two countries does not appear to have made it more difficult for other buyers or sellers to enter this market. Other countries that so desire can go into the market and bid Malaysian tin away from the United States if they are willing to pay the price. For this reason, three sets of results for the refined tin model are shown in Table 5–5. The first is for the full model; the second is for a modified model that excludes only the dummy variable (P_{ij}) reflecting the preference of the United States for Malaysian tin; and the third is for a modified model that excludes all the independent variables except the export potential of country i, the import potential of country j, and the distance between countries.

The results indicate that export potential, import potential, and distance alone can explain between 40 and 46 percent of the variation in trade flows of refined tin, which is a higher percentage than found for aluminum, refined copper, and refined nickel. Table 5–4 also indicates clearly the importance of the American preference for Malaysian tin. This variable by itself increases the ability of the model to explain trade in refined tin by 53 percent in 1955, 42 percent in 1965, and 31 percent in 1975. In sharp contrast to the findings for other refined metals, however, ownership ties, political blocs, and the neighboring country effect collectively have little effect on the structure of refined tin trade. In no instance does the addition of these variables appreciably improve the ability of the model to explain trade flows. Moreover, rarely are the coefficients for these variables significant, and in many instances they have the wrong sign.

These findings suggest that the international market for refined tin, unlike the market for tin concentrate and the other refined and

Table 5–4. Trade in Refined Tin (Thousands of Metric Tons)

	United States	Japan	United Kingdom	France	Germany	Italy	Netherlands	Benelux	Other[a]
					1955				
Malaysia	42.87	4.81	3.36	2.82	0.54	2.35	2.06	0.22	11.80
United Kingdom	4.56			0.05	0.13		0.43	1.68	2.70
Netherlands	7.27	0.04	0.17	5.00	2.95	0.87		0.02	4.00
Belgium	6.10		0.46	1.15	0.69	0.03	0.19		1.33
Indonesia	0.75	0.60		0.09	3.63	0.03			0.28
Zaire	0.38							2.06	0.09
United States			0.19		0.03				0.65
Other[a]	0.40	0.05	0.02	0.01		0.60	0.03	0.01	3.40
					1965				
	United States	*Japan*	*United Kingdom*	*France*	*Germany*	*Italy*	*Netherlands*	*Benelux*	*Other[a]*
Malaysia	28.26	14.70	2.68	3.13	1.68	3.98	2.37	0.89	11.70
United Kingdom	1.16			0.90	1.12		0.44	0.17	1.20
Netherlands	0.53		0.61	2.20	7.24	1.11		0.89	1.80
Benelux	0.10		0.15	1.84	1.15	0.03	0.74		0.07
Thailand	5.90		0.15	1.51	1.10	0.10	0.60		0.40

Nigeria	1.41		7.50	0.23	0.80		1.28		0.45
United States			0.03		0.08		0.20	0.11	
Bolivia	0.53				0.10				
Indonesia	0.16	0.04		0.65	0.15	0.01		0.01	
Other[a]	0.09	0.02	0.06	0.09	1.40	0.10	0.05	0.60	1.20

1975

	United States	*Japan*	*United Kingdom*	*France*	*Germany*	*Italy*	*Nether-lands*	*Benelux*	*Other*[a]
Malaysia	25.06	15.80	1.45	4.73	2.44	4.69	0.72	1.46	11.60
United Kingdom	0.86			0.93	1.32	0.08	1.01	0.15	0.62
Thailand	6.77	5.68			3.71	0.50	0.64		
Indonesia	4.53			1.80	4.03	0.75			0.40
Bolivia	1.10			0.35	0.50		1.78		2.00
United States			0.09		0.07		1.80		0.80
Nigeria	0.20		2.50	0.17	0.69		0.53		
Brazil	1.04						0.025		
Australia	0.26	0.07	1.05						0.30
Netherlands	0.07		1.20		0.30	0.22		0.21	2.50
Benelux				0.73	0.65	0.07	0.24		1.20
Other[a]	3.70			1.09	0.41		0.95	0.67	2.50

Sources: International Tin Council (various years); *Metal Statistics* (various years).

[a]Figures for "other" countries are estimates.

Table 5–5. Results of the Refined Tin Model

	Constant	D_{ij}	XP_i	MP_j	$N_{ij}M_{ij}$	$B1_{ij}M_{ij}$	$B2_{ij}M_{ij}$	$B3_{ij}M_{ij}$	$B4_{ij}M_{ij}$	$O_{ij}M_{ij}$	$P_{ij}M_{ij}$	R^2	n
1975	0.222 (0.586)	−0.121 (0.075)	0.063* (0.010)	0.042* (0.015)	−0.102 (0.283)		−0.913 (0.288)	−0.053 (0.199)	−0.046 (0.145)	−0.021 (0.200)	0.399* (0.041)	0.77	84
	−0.742 (0.867)	−0.107 (0.112)	0.096* (0.014)	0.083* (0.022)	−0.066 (0.425)		−0.213 (0.433)	−0.051 (0.299)	0.035 (0.218)	−0.046 (0.300)		0.46	84
	−0.716 (0.609)	−0.118 (0.086)	0.093* (0.013)	0.085* (0.021)								0.46	84
1965	0.322 (0.504)	−0.137* (0.070)	0.053* (0.010)	0.018 (0.016)			−0.108 (0.202)	0.565 (1.339)	0.185 (0.080)	0.426* (0.149)	0.497* (0.040)	0.84	68
	−0.929 (0.938)	−0.127 (0.132)	0.094* (0.018)	0.080* (0.029)			−0.573 (0.384)	1.135 (2.539)	0.156 (0.151)	0.234 (0.281)		0.42	68
	−0.605 (0.833)	−0.163 (0.117)	0.096* (0.017)	0.085* (0.028)								0.40	68
1955	−0.294 (0.340)	−0.120* (0.055)	0.031* (0.007)	0.051* (0.009)		0.521 (0.332)	0.237 (0.281)	0.132 (0.449)		[a]	0.521* (0.021)	0.95	52
	−1.564 (1.239)	−0.089 (0.206)	0.094* (0.027)	0.144* (0.033)		0.790 (1.242)	−0.576 (1.046)	0.469 (1.680)		[a]		0.43	52
	−1.430 (1.201)	−0.081 (0.197)	0.089* (0.025)	0.143* (0.032)								0.42	52

Source: Based on the authors' computations.

*Significant at the 95 percent probability level, one-tailed test.

[a]In 1955 perfect multicollinearity existed between $O_{ij}M_{ij}$ and the sum of $B1_{ij}M_{ij}$ and $B2_{ij}M_{ij}$. For this reason, $O_{ij}M_{ij}$ was excluded from the model. The variables $B1_{ij}M_{ij}$ and $B2_{ij}M_{ij}$ thus reflect the influence of ownership ties as well as political blocs on trade.

unrefined metals examined, may approximate the type of free market often assumed in the traditional trade literature. Here, apparently, political blocs, ownership ties, product differentiation, and the neighboring country effect do not strongly mold the structure of trade or create rigidities in trade flows that inhibit new producers and new consumers trying to enter the market. The preference of the United States for Malaysian tin does affect the pattern of trade, but the manner in which this preference is exercised, through the competitive Straits tin market, suggests that it can constrain the flow of tin trade only so long as the United States is willing to outbid other importing countries for this source of supply.

INTERNATIONAL TRADE IN ZINC

Zinc is an important metal. In recent years its volume of output has been exceeded only by iron and steel, aluminum, and copper. It is also widely traded. Over fifty countries produce zinc concentrate, and over thirty possess smelter capacity for refining zinc. Asarco, Texasgulf Sulfur, Rio Tinto, Mitsui, and other multinational firms play an important role in the production and trade of zinc. The significance of such international ownership ties and other variables in shaping zinc trade patterns is assessed in this section with a model similar to that used for tin. Since zinc enters international trade in both concentrate and refined metal forms, separate models are specified for each of these stages of production.

Zinc Concentrate Trade

Trade matrices showing the average annual trade over three-year periods centered on 1965 and 1975 are shown in Table 5–6.[10] These matrices, like those for tin, identify the trade flows between the major exporting and importing countries outside the Communist bloc. Trade involving the minor exporting or importing states is reported under the category of "other." Major exporting countries include Canada, Peru, Australia, Sweden, and Mexico. The major importing countries are Japan, Benelux, Germany, France, and the United States.

In the zinc concentrate model, trade between the major exporting and importing countries (T_{ij}) shown in Table 5–6 is assumed to depend on the following variables:

1. The export potential of country i (XP_i). Mine capacities for zinc-exporting countries are difficult to obtain, so therefore this variable is estimated by the largest annual quantity of zinc concentrate exports from country i during the preceding five years measured in thousands of metric tons of contained zinc.[11]

Table 5–6. Trade in Zinc Concentrates (Thousands of Metric Tons Contained Metal)

	1975									
	Japan	*Benelux*	*Germany*	*France*	*Netherland*	*United States*	*United Kingdom*	*Norway*	*Italy*	*Others*[a]
Canada	335.3	352.0	255.1	102.3	69.1	99.8	13.4	3.2	71.2	102.1
Peru	300.5	9.8	22.3	111.4	20.9	5.9	56.1		48.3	16.1
Australia	205.7	31.2	7.7	9.3	122.1	3.6	29.7	7.8		24.1
Sweden		42.6	69.2	33.4	6.3			52.1		19.6
Mexico	24.1	25.2	39.7	3.8	7.5	10.7			15.1	6.5
Republic of South Africa		4.4	66.3							21.2
Iran	19.5	4.7	5.3	7.1	1.0		7.2			12.7
Greenland		6.0	22.3		6.1	0.3			13.1	6.5
Ireland		20.9	39.1	42.5	2.9	0.3	13.2		9.1	12.1
Bolivia	23.1	0.1	5.4	8.4		0.6				3.2
United States	17.1	18.5	15.1	0.1	3.9		3.7	3.3	5.3	4.5
Netherlands		32.1					2.9			1.2
Others[a]	125.1	67.6	48.4	44.2	47.1	21.1	1.6	6.4	31.4	140.1

1965

	Japan	*Benelux*	*Germany*	*France*	*Netherlands*	*United States*	*United Kingdom*	*Norway*	*Others*[a]
Canada	32.6	231.6	34.6	58.2	9.1	221.4	9.3	9.0	85.1
Peru	186.6	3.8	10.7	42.6	2.6	65.1		1.3	18.6
Australia	35.3	12.1	4.6	1.6	0.8	3.1	184.0	14.0	21.7
Sweden		41.3	38.6	15.1	.9		0.5	47.3	9.4
Mexico	39.2	3.4		3.8		100.6			32.5
Republic of South Africa	2.8	7.1		1.3		9.1	16.0		5.6
Iran	5.0	9.3	6.4	11.1			18.0		5.2
France		71.6	12.1	13.2	13.6				7.6
Morocco		1.3		70.5	0.9	3.8			7.9
Zaire		76.6	6.4	13.1			4.0		15.1
Germany		9.1		5.2	12.6	7.2	5.0		7.2
Italy		5.6	3.6	11.1					20.1
Algeria		3.0		34.6	0.6	1.7		0.7	2.1
Others[a]	72.1	23.7	27.4	66.9	5.4	19.5	23.4	16.0	130.2

Sources: *Metal Statistics* (various years); U.S. Bureau of Mines (various years); Great Britain, Overseas Geological Surveys (various years).
[a]Figures reported for "other" countries are estimates.

2. The import potential of country j (MP_j). For similar reasons, this variable is estimated by the largest annual volume of zinc concentrate imports into country j over the preceding five years measured in thousands of metric tons of contained zinc.[12]

3. The ocean distance between country i and country j (D_{ij}) in thousands of nautical miles, as reported by the U.S. Naval Oceanographic Office (1965).

4. A dummy variable (S_{ij}) to take account of the unusual nature of the lead-zinc bulk concentrates produced by certain mines in Canada and Australia. The imperial furnace is the only smelter suitable for treating such ores. Importing countries with imperial smelters include the United Kingdom, France, Germany, Italy, and Japan. To capture this constraint on zinc concentrate trade, S_{ij} takes the value of one if country i is Canada or Australia and if country j possesses an imperial smelter. Otherwise, it is zero. This variable is then multiplied by the maximum amount of zinc concentrate trade possible (M_{ij}) between country i and country j, where M_{ij} is assumed to equal XP_i or MP_j, whichever is smaller.

5. A dummy variable for the neighboring country effect (N_{ij}) that takes the value of one if country i and country j share a common border, and zero otherwise. This variable is also multiplied by the maximum amount of trade (M_{ij}) possible between the two countries.

6. Four dummy variables for political blocs. The first ($B1_{ij}$) takes the value of one for trade flows between Benelux and Zaire; the second ($B2_{ij}$) for trade flows between the United Kingdom and members or former members of the British Commonwealth; the third ($B3_{ij}$) for trade flows between France and the French Community (Morocco and Algeria); and the fourth ($B4_{ij}$) for trade flows between members of the European Economic Community. All these variables are multiplied by the maximum amount of trade possible (M_{ij}) between countries.

7. A dummy variable for ownership ties (O_{ij}) that takes the value of one when an appreciable portion (25 percent or more) of the zinc mine capacity in country i is owned by interests in country j.[13] Again, this variable is multiplied by the maximum amount of trade possible (M_{ij}) between countries.

The coefficients for the zinc concentrate model are shown in Table 5–7 for both the full model and a modified model that includes as independent variables only export potential, import potential, and distance. This table also shows the coefficient of determination (R^2) and the number of observations (n) for each equation.

The results indicate that the percentage variation of trade flows accounted for by export potential, import potential, and distance only increased from 27 percent in 1965 to 51 percent in 1975. The differ-

Table 5–7. Results of the Zinc Concentrate Model

	Constant	D_{ij}	XP_i	MP_i	$S_{ij}M_{ij}$	$N_{ij}M_{ij}$	$B1_{ij}M_{ij}$	$B2_{ij}M_{ij}$	$B3_{ij}M_{ij}$	$B4_{ij}M_{ij}$	$O_{ij}M_{ij}$	R^2	n
1975	− 7.486 (9.445)	−4.629* (1.440)	0.106* (0.019)	0.057* (0.013)	0.137* (0.035)	−0.113 (0.176)		−0.326 (0.191)		−0.311 (0.508)	0.290* (0.605)	0.63	106
	−22.989* (9.408)	−4.423* (1.479)	0.158* (0.017)	0.028* (0.013)								0.51	106
1965	−10.912 (7.897)	−1.0692 (0.909)	0.080* (0.024)	0.049* (0.018)	0.001 (0.047)	0.136* (0.080)	0.186 (0.251)	0.113 (0.081)	0.338 (0.306)	−0.094 (0.277)	0.325* (0.051)	0.63	103
	−19.300* (9.824)	−1.452 (1.128)	0.145* (0.027)	0.073* (0.023)								0.27	103

Source: Based on the authors' computations.

*Significant at the 95 percent probability level, one-tailed test.

entiated nature of zinc ores, neighboring country effect, political blocs, and ownership ties explained an additional 36 percent in 1965, but only an additional 12 percent in 1975 of trade flow variation. The combined effect of all the independent variables has remained constant at 63 percent over the ten-year period.

The results for individual variables show that the coefficients for export potential and import potential have the right signs and are significantly different from zero. The distance variable also has the correct sign, but it is significant only in the 1975 trade equation.

In both periods the coefficient for ownership ties is positive and highly significant. The coefficient of the differentiated nature of zinc concentrates is positive in both years, though only significant in 1975. In contrast, the results provide little evidence that political blocs greatly influence the flow of zinc concentrate trade. The coefficients for these variables are not significant, and in some cases they have the wrong sign. The final variable considered by the model is the neighboring country effect. Its coefficient is positive, as expected, and significantly different from zero in 1965, but it turns negative and insignificant in 1975.

The results suggest that ownership ties, the differentiated nature of ores (in 1975), and the neighboring country effect (in 1965) are important forces shaping the flow of trade in zinc concentrates. These findings are consistent with many of the earlier studies on metal trade patterns that found that ownership ties have a substantial impact on trade patterns for ores and concentrates.

According to the coefficients of determination, the full model explains nearly two-thirds of the variation in trade flows for both time periods examined. What remains unexplained is due to variables not explicitly taken into account in the model. One such factor is the extensive use of long-term contracts between certain trading countries. Substantial quantities of zinc concentrates, for example, are shipped from Canada and Australia to Japan under such contracts, and the same is true for Canadian concentrates destined for Belgium. Since the model does not include a variable for long-term contracts, it anticipates far less trade between these three sets of trading partners than actually takes place.

Another factor whose influence is not fully captured by the model is the differentiated nature of zinc ores. In addition to the preference to use the Imperial furnace for processing lead-zinc bulk concentrates (which the model does consider), there are certain processing facilities that require high-quality ores. In particular, the electrolytic smelter must use higher quality ores than other smelters. Because data on the quality of ore coming from different mines is unavailable, this aspect of the differentiated nature of zinc ores cannot be explicitly taken into account by the model.

Refined Zinc Trade

Trade matrices for refined zinc trade are shown in Table 5–8 that indicate the average annual volume of trade between the major exporting and importing countries outside the Communist bloc over three-year periods centered on 1955, 1965, and 1975. The United States, the United Kingdom, Germany, France, and Sweden are among the most important importing countries, whereas Canada, Benelux, Australia, Mexico, and Peru are among the most important exporting countries.

The model used to analyze trade patterns for refined zinc contains the following independent variables:

1. The export potential of country i (XP_i), estimated by the largest annual volume of refined zinc exports from country i over the preceding five years measured in thousands of metric tons.[14]

2. The import potential of country j (MP_j) estimated by the largest annual volume of refined zinc imports into country j over the preceding five years measured in thousands of metric tons.[14]

3. The ocean distance between country i and country j (D_{ij}) in thousands of nautical miles, as reported by the U.S. Naval Oceanographic Office (1965).

4. A dummy variable for the neighboring country effect (N_{ij}) multiplied by the maximum amount of refined zinc trade possible (M_{ij}) between importing country j and exporting country i, where M_{ij} is again assumed equal to the smaller of XP_i or MP_j.

5. Three dummy variables for political blocs. The first ($B1_{ij}$) represents the special ties between Belgium and Zaire; the second ($B2_{ij}$) the special ties between the United Kingdom and members or former members of the British Commonwealth; and the third ($B3_{ij}$) the special ties between members of the European Economic Community. These variables are multiplied by (M_{ij}), the maximum amount of trade possible between countries.

6. An ownership tie variable (O_{ij}) that equals the amount of smelter capacity in country i controlled (at least 50 percent ownership) by firms in country j.

In addition to the full model, which includes all of the preceding variables, a modified model containing only the first three variables was estimated. The results are shown in Table 5–9, and they indicate that export potential, import potential, and distance have had a declining influence on trade, accounting for 40 percent of the variation in trade patterns in 1955, 36 percent in 1965, and 33 percent in 1975. The coefficients for the export potential and import potential variables

Table 5–8. Trade in Refined Zinc (Thousands of Metric Tons)

1975

	United States	*United Kingdom*	*Germany*	*France*	*Sweden*	*Netherland*	*Italy*	*Brazil*	*Benelux*	*Other*[a]
Canada	234.5	42.6	3.4	0.6	0.1	0.4	0.2	2.0	1.6	10.1
Benelux	23.2	13.2	71.0	32.2	1.1	11.0	11.3	5.0		31.1
Australia	28.6	12.1	0.3			0.5		0.1	2.3	2.8
Mexico	31.2	8.4	1.6	3.5	0.6	0.6	3.0	7.1	9.3	14.4
Peru	21.2	0.2	0.6	0.2		0.4	3.2	11.6	1.9	12.0
Zaire	19.4		1.0	0.2	0.2				5.6	1.9
Germany	25.1	9.3		10.1	0.1	17.2	12.2	0.7	1.7	5.6
Netherlands	7.2	52.0	17.2	9.3	1.2		0.4	0.1	6.4	4.1
Finland	18.7	32.3	3.4	0.7	13.2	0.2	1.6			2.9
Japan	20.0	0.9	0.8		0.1	0.1	0.5	1.0	1.4	5.9
Other[a]	55.4	23.1	21.1	8.6	18.0	4.4	9.6	7.1	9.2	129.7

1965

	United States	*United Kingdom*	*Germany*	*France*	*Sweden*	*India*	*Italy*	*Brazil*	*Other*[a]
Canada	84.3	95.5	5.5	0.8		14.1	5.0	1.1	17.1
Benelux	11.1	7.5	57.8	9.6	2.4	0.3	5.9	2.8	30.2
Australia	8.6	23.3	2.1		0.2	0.3	4.4	13.3	36.5
Mexico	14.3	0.5			1.1		0.1	6.1	6.9
Peru	14.6	6.8	3.6	0.4	0.6	0.3	2.0	13.3	12.1
Zaire	10.2	4.6	10.7				1.6		8.1
Germany	6.1	1.5		1.0	0.1	0.3	8.1	0.4	2.1
Netherlands	0.1	0.8	15.4	6.3	0.3	0.1	0.7	0.4	4.0
Other[a]	14.1	39.3	24.1	7.1	15.2	15.6	2.0	9.1	62.1

	United States	*United Kingdom*	*Germany*	*France*	*Sweden*	*India*	*Other*[a]
Canada	101.4	74.3	0.2	0.1		3.3	6.5
Benelux	18.3	14.6	29.1	26.2	7.2	1.1	4.1
Australia	4.3	11.2				16.7	2.1
Mexico	13.7	14.5	0.2	0.2	2.5	0.7	12.1
Peru	7.0	1.7	0.6				4.5
Zaire	14.3	8.2					3.1
Germany	6.7	3.8		5.1	0.2		9.1
Norway	0.4	1.1	9.1	10.1	9.4		2.2
United States		14.6	6.4	0.1	5.6	0.1	4.1
Other[a]	15.1	5.4	16.1	1.5	2.1	3.5	30.1

Sources: *Metal Statistics* (various years); *Mineral Yearbooks* (various years); Great Britain, Overseas Geological Surveys (various years).

[a]Figures reported for "other" countries are estimates.

Table 5–9. Results of the Refined Zinc Model

	Constant	D_{ij}	XP_i	MP_j	$N_{ij}M_{ij}$	$B1_{ij}M_{ij}$	$B2_{ij}M_{ij}$	$B3_{ij}M_{ij}$	O_{ij}	R^2	*n*
1975	−4.385 (3.420)	−0.046 (0.385)	0.028* (0.016)	0.039* (0.008)	0.488* (0.051)	0.050 (0.372)	0.077* (0.046)	0.007 (0.045)	0.198* (0.111)	.85	87
	−2.757 (6.267)	−1.430* (0.697)	0.091* (0.031)	0.072* (0.014)						0.33	87
1965	−2.386 (1.585)	0.186 (0.196)	0.022* (0.007)	0.029* (0.008)	0.412* (0.023)		0.389* (0.020)	0.072* (0.037)	0.001 (0.021)	0.95	63
	−4.775 (4.864)	−0.658 (0.619)	0.098* (0.024)	0.090* (0.025)						0.36	63
1955	−1.517 (2.460)	−0.037 (0.296)	0.025* (0.015)	0.042* (0.013)	0.437* (0.030)		0.388* (0.037)		[a]	0.91	52
	−4.241 (6.076)	−0.768 (0.724)	0.127* (0.034)	0.098* (0.031)						0.40	52

Source: Based on the authors' computations.

*Significant at the 95 percent probability level, one-tailed test.

[a]The ownership tie variable was excluded from the 1955 full model because its inclusion produced implausible results.

have the correct sign and are significant at the 95 percent probability level in both models. The coefficient for the distance variable also has the correct sign (except in the 1965 full model), but it is significant only in 1975.

The results for the full model reveal that the other independent variables can explain an additional 51 to 59 percent of the variation in trade patterns. The neighboring country effect and the British Commonwealth political bloc are particularly important determinants of refined zinc trade. The coefficients for these variables have the correct sign and are significant for all of the years examined. Ownership ties, the special ties between Zaire and Belgium, and the European Economic Community appear to have less influence on refined zinc trade. With the exception of ownership ties in 1975 and the European Economic Community in 1965, these variables are insignificant.

Overall the results for zinc correspond more closely to the findings of earlier studies of metal trade patterns than those for tin. Ownership ties are particularly important in shaping trade flows of concentrates, whereas at the refined metal stage certain political blocs and the neighboring country effect are far more significant. The latter variables appear to introduce rigidities in the patterns for refined zinc trade that one does not find for refined tin. However, at the concentrate level, zinc and tin are similar in one respect; that is, trade in both of these commodities is significantly influenced by the differentiated nature of their ores.

IMPLICATIONS FOR LATIN AMERICA'S TRADE AND RESOURCE POLICIES

Mining and mineral processing are important sources of foreign exchange and government revenues for a number of Latin American countries. For this and other reasons, public involvement in the mineral sector has been growing over time. In this regard the last twenty-five years have witnessed two particularly important developments in Latin America as well as elsewhere. The first is the increasing incidence of public ownership in the mineral sector. Far less frequently are projects completely owned and controlled by the multinational resource companies today than was the case in the 1950s. Indeed, many countries now insist that the government hold a major interest in domestic mining ventures, and in some countries governments have assumed total control. The second major development involves the aspirations and efforts of many Latin American countries to increase the amount of mineral processing done domestically.

While such efforts may enhance the benefits producing countries realize from their mineral wealth, they may create problems as well. Countries that reduce or completely sever international ownership ties may lose the preferential access to certain markets that the multinational resource companies can provide. Countries that upgrade their domestic processing operations so that they export refined rather than unrefined mineral commodities may find a large portion of the market they are trying to enter foreclosed by political blocs, ownership ties, and other considerations unless they are willing to accept less for their products than other countries.

The models described in this chapter and the studies of mineral trade patterns based on this model suggest that ownership ties, political blocs, product differentiation, the neighboring country effect, and long-term contracts are often as important, or perhaps even more important, in shaping trade flows than the variables (export potential, import potential, and distance) usually considered in analyzing trade problems. While there are exceptions to this finding, as refined tin trade illustrates, they appear to be few.

This does not necessarily mean that governments should stop pursuing efforts to increase national control over domestic mining operations or to promote downstream processing, but it does suggest the need to consider carefully the impact that such actions may have on a country's access to markets. This, in turn, requires an understanding of the nature of trade patterns and the various factors that faciliate or constrain trade flows. The model described in this chapter is designed specifically for this purpose and can be useful in this endeavor.

NOTES

1. Structure of trade models have rarely been used to analyze trade in individual commodities. Tilton (1966) and Margueron (1966) are the only previous attempts of which we are aware to apply this type of model to individual mineral commodities.

2. Dummy variables may also be used for O_{ij} and L_{ij} if the available data for these two variables do not allow precise quantification.

3. In nickel, a model of trade was estimated only for the refined metal. Trade flows in semiprocessed nickel, which includes ore, matte, concentrates, and nickel oxide, are few in number and easily assessed qualitatively.

4. The sources for this information are the same as those for Table 5–2.

5. The sources for this information are the same as those for Table 5–2.

6. Information on ownership ties was obtained from Engineering and Mining Journal (1975); *World Mines Register 76/77* (1976); U.S. Bureau of Mines (annual); U.S. Department of Commerce (1953); Schanz (1954); Tilton (1966); and discussions with corporate officials.

7. The sources for this information are those cited in Table 5–4.

8. The sources for this information are those cited in Table 5–4.

9. The sources for ownership ties are the same as those noted earlier for tin concentrates.

10. Data are not available to construct a trade matrix for 1955.

11. The sources of this information are given in Table 5–6.

12. The sources of this information are given in Table 5–6.

13. Information on ownership ties was obtained from Engineering and Mining Journal (1975): *World Mines Register 76/77* (1976): U.S. Bureau of Mines (annual): Tilton (1966): and discussions with corporate and government officials.

14. The sources for this information are given in Table 5–8.

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